# COMPARISON OF PREDICTED AND OBSERVED TIDES AT MONTEREY, CALIFORNIA

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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

Comparison of Predicted and Observed

Tides at Monterey, California

by

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## ABSTRACT

A comparison of the predicted and observed tides at Monterey, California conducted over the period of a year revealed that the hourly water-level differences did not exceed ± 0.9 feet in magnitude. 263 water-level anomalies of duration up to 362 hours were identified, of which 42 were of duration greater than twelve hours. It was determined that change in atmospheric pressure is the dominant causitive factor of hourly water-level differences and that the water-level response is approximately hydrostatic. The changes in atmospheric pressure associated with the 42 water-level anomalies examined were found to be manifestations of the eastward or westward migration of the isobaric gradient due to either intensification or movement of the quasi-permanent high and low pressure systems in the region.

TABLE OF CONTENTS

## LIST OF TABLES

LIST OF FIGURES

## ACKNOWLEDGEMENTS

The author desires to express his appreciation to Dr. Warren C. Thompson for his assistance and constructive criticism during the course of this study and who suggested that it be undertaken; to Mr. Robert A. Cummings, Chief of the Tides Branch, National Ocean Survey for analyzing the tide data used in this study.

# I. INTRODUCTION

The astronomical tides are periodic undulations of the sea surface height which are readily predictable. Meteorological and oceanographical factors exert short-term influences which can cause additional deviations from the mean ocean level; these additional water-level deviations are superimposed upon those caused by the tides and are not predictable with the exception of wind-induced storm tides generated over wide continental shelves.

It was the purpose of this study to examine the nature of the non-astronomically produced water-level deviations at a selected tide station on the California coast over the period of a year and to inquire about their causes. These deviations were derived by comparing the predicted tide with the observed tide hourly. It was found that the observed water-level deviated from the predicted over varying periods of time ranging from less than six hours to as long as 15 days. These periods were considered anomalous.

Initial examination of various factors that might induce anomalous water levels indicated that atmospheric pressure variations were a dominant factor. Accordingly, the effect of atmospheric pressure was examined in detail to determine the extent of its influence in producing the hourly water-level differences and the anomalous periods observed.

## II. COLLECTION AND ANALYSIS OF TIDE DATA

The observed tide data were recorded on a standard recording tide gage maintained by the Naval Postgraduate School on Monterey Municipal Wharf No. 2, Monterey, California (Figure 1). The recording period selected for this study was an annual cycle extending from 28 January 1971 through 2 February 1972, a period of 370 days. Selection of the calendar year 1971 would have been more desirable but the tide gage required repair in January and recording during that month was incomplete. Recording was continuous throughout the entire period selected with the exception of three intervals totaling forty hours which required interpolation.

The monthly tide rolls from the tide gage were reduced to yield hourly water-level heights, and heights and times of high and low waters, following the standard procedures used by the National Ocean Survey (Coast and Geodetic Survey, 1965). Heights were measured to the closest 0.1 foot and resolution of the time of high and low waters was to the closest six minutes.

The Tides Branch, National Ocean Survey, Rockville, Maryland performed a harmonic analysis of the observed tide data, isolating 37 harmonic constituents (Appendix A). Utilizing all 37 constituents, predicted hourly heights and heights and times of high and low waters were computed for the period 1 February 1971 through 31 January 1972. Only the hourly heights were used in this study. From the predicted hourly heights, the differences between the observed and predicted hourly water levels were computed. This residual constituted the hourly water-level differences

that form the basic data used in this study. The variability of the values of hourly water-level difference with time indicate a precision of $\pm$ 0.1 foot for the data.

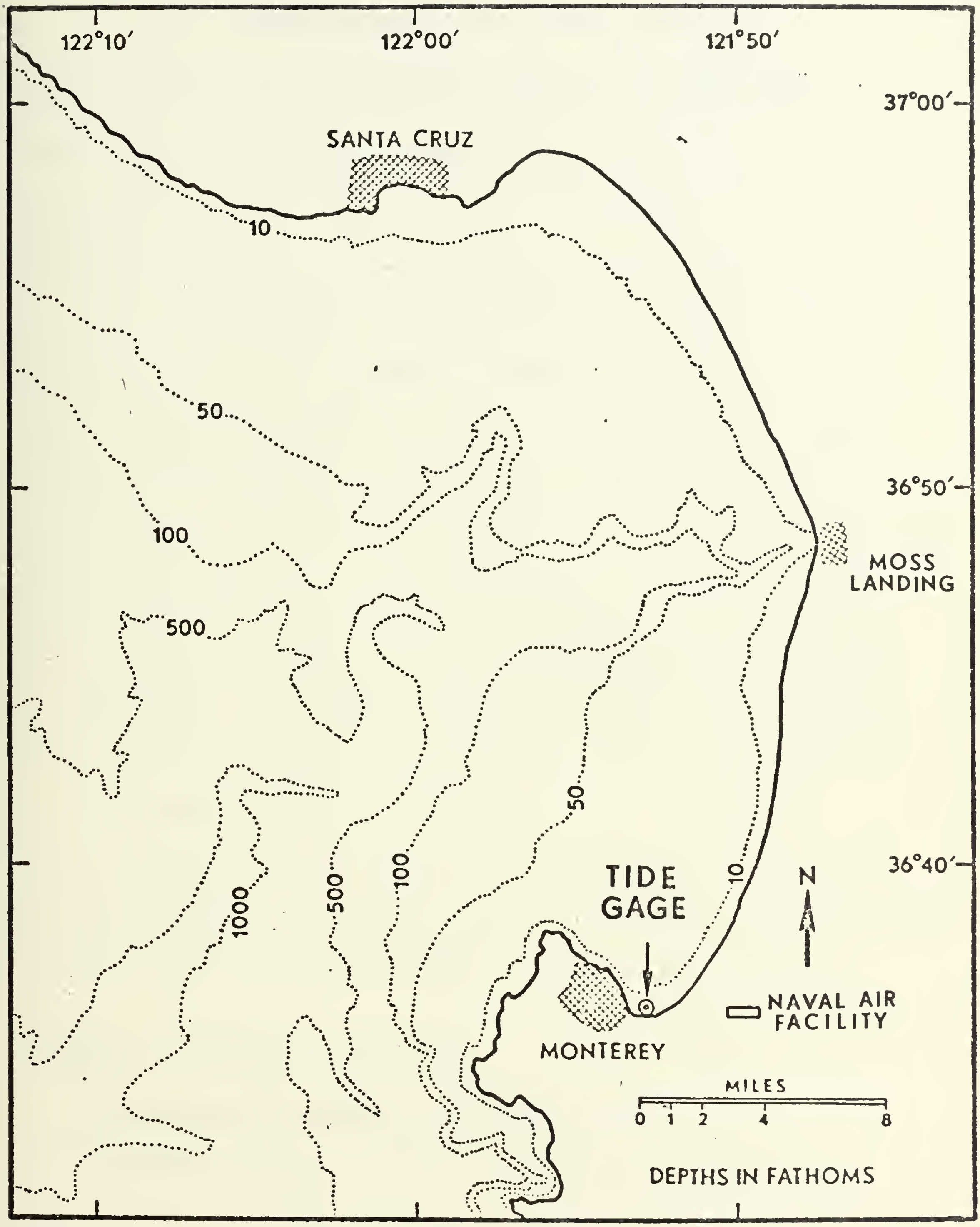


Figure 1: TIDE GAGE LOCATION, MONTEREY, CALIFORNIA

# III. DISTRIBUTION OF WATER-LEVEL DEVIATIONS

## A. STATISTICAL DISTRIBUTION OF HOURLY WATER-LEVEL DIFFERENCES

The difference between the observed and predicted tide height at a given time is referred to here as a water-level difference. A given water-level difference is termed positive (negative) when the observed water level is greater (less) than the predicted height. A sample of the hourly water-level difference data appears in Figure 3A.

The differences between the observed and predicted hourly water levels were first examined independently of trends appearing in the hourly time series. The frequency distribution of the 8760 water-level differences contained in the year of tide data is shown in Table 1 and Figure 2. The distribution is very nearly normal about a zero water-level difference. The extreme water-level differences noted did not exceed $\pm$ 0.9 foot, and sixty-three percent of the hourly differences fell in the range from +0.1 to -0.1 foot.

The distribution of hourly water-level differences by months is summarized in Table 2. It may be noted that the fall and winter months generally exhibit the greatest number of water-level differences.

## B. PERIODS OF ANOMALOUS WATER LEVEL

### 1. Definition of Anomalous Water-Level Period

Examination of the hourly water-level data revealed that throughout the year there were periods of consecutive hourly water-level differences of like sign varying from two to 362 hours in duration. Noting that the precision of both the observed and predicted hourly water levels was 0.1 foot, the decision was made to consider only hourly

water-level differences equal to or greater than an absolute value of 0.2 feet as indicating a real water-level difference. Accordingly, the data were filtered so as to delete all values of -0.1, 0.0 and +0.1 feet. A sample of the hourly water-level difference data before and after filtering is presented in Figures 3A and 3B.

In summary, a water-level anomaly, for the purposes of this study, is defined as follows:

a. An anomaly begins when the hourly water-level differences become $\pm$ 0.2 feet or greater and ends when the hourly water-level differences fall below $\pm$ 0.2 feet. It follows that a water-level anomaly consists of like signed hourly water-level differences. The existance of hourly values less than $\pm$ 0.2 feet was tolerated within the interval of a water-level anomaly only when it appeared that they were indicative of the general trend of the anomaly.

b. A water-level anomaly has a duration of two hours or greater.

2. Occurrence of Water-Level Anomalies

All water-level anomalies occurring during the year, as defined above, were identified from the time series of hourly water-level differences, and their frequency of occurrence by duration and month are presented in Table 3. It may be noted from the table that of the 263 anomalies found, only 21 were of a duration longer than 24 hours, with a tendency for the longer anomalies to occur in the fall and winter months. There was a slight tendency for a greater number of short anomalies (11 hours or less) to occur in the spring and summer months. Those anomalies of duration 12 hours or longer were examined in detail and their properties are tabulated in Appendix B.

Attention was also directed to periods of extreme water-level difference, considered here to include all values of hourly water-level difference equal to or greater than $\pm 0.4$ feet (667 values or eight percent of the total number of hourly water-level differences from Table 1). A summary of the occurrence of those extreme periods by duration and month is given in Table 4. It may be noted that the distribution by months is irregular, with a tendency for a greater occurrence in the fall and winter months. Of the 61 extreme water-level periods identified, 47 (77%) were of a duration less than 12 hours. The properties of these extreme periods are tabulated in Appendix C.

TABLE I: FREQUENCY DISTRIBUTION OF HOURLY WATER-LEVEL DIFFERENCES

| DIFFERENCE (FEET) | NO. VALUES | PERCENT | REMARKS |
|---|---|---|---|
| +0.9 | 6 | 0.06 | |
| +0.8 | 5 | 0.05 | |
| +0.7 | 33 | 0.37 | |
| +0.6 | 39 | 0.44 | 1617 positive values |
| +0.5 | 79 | 0.90 | greater than 0.1 foot |
| +0.4 | 179 | 2.04 | |
| +0.3 | 434 | 4.95 | |
| +0.2 | 842 | 9.61 | |
| +0.1 | 1593 | 18.11 | |
| 0.0 | 2160 | 24.65 | 5552 values (63.15%) |
| -0.1 | 1799 | 20.39 | |
| -0.2 | 896 | 10.22 | |
| -0.3 | 369 | 4.21 | |
| -0.4 | 173 | 1.97 | |
| -0.5 | 86 | 0.98 | 1591 negative values less |
| -0.6 | 48 | 0.54 | than -0.1 foot. |
| -0.7 | 15 | 0.17 | |
| -0.8 | 2 | 0.02 | |
| -0.9 | 2 | 0.02 | |
| TOTAL | 8760 | 99.70 | |

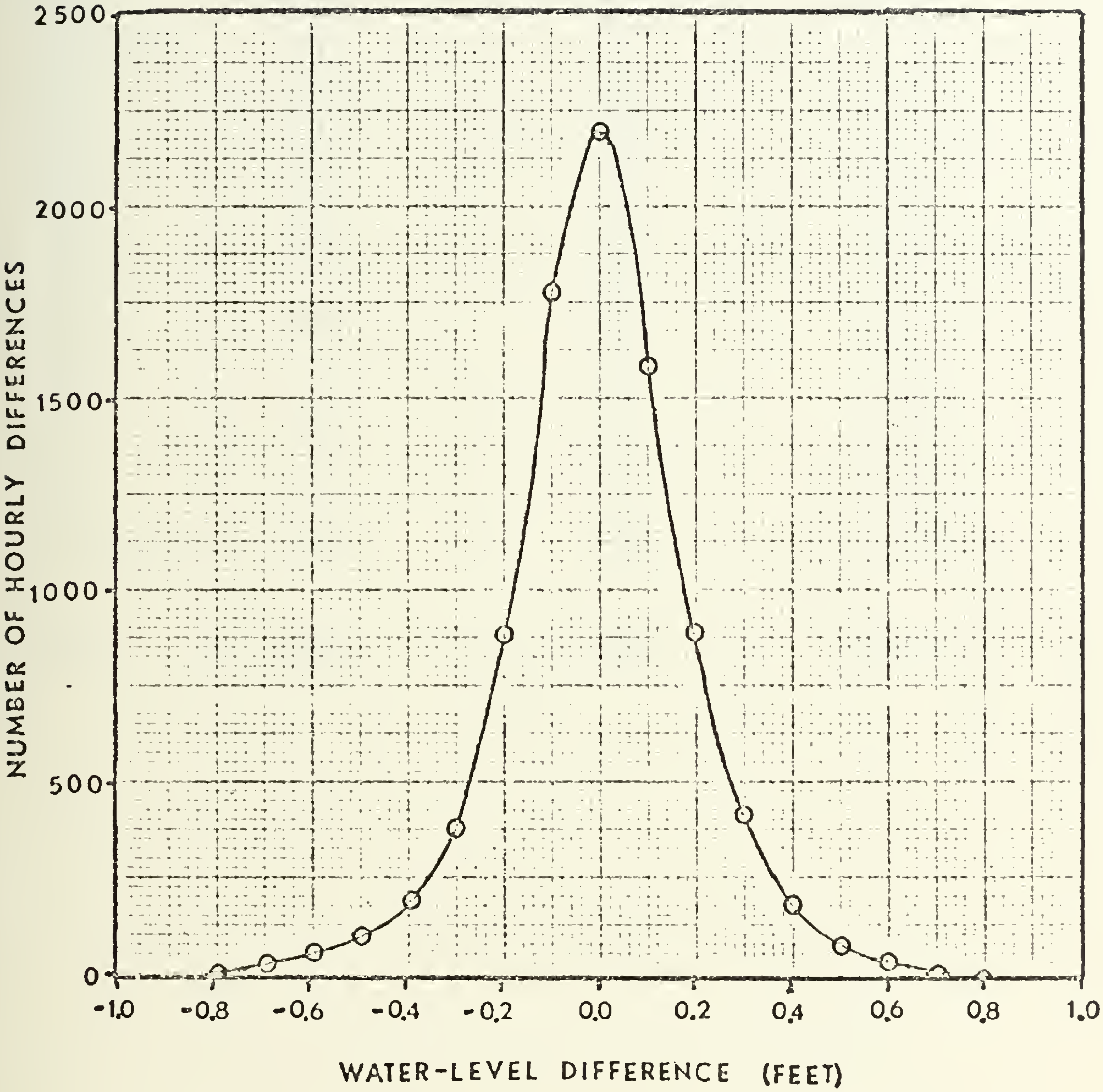


FIGURE 2: FREQUENCY DISTRIBUTION OF HOURLY WATER-LEVEL DIFFERENCES

TABLE 2: MONTHLY DISTRIBUTION OF HOURLY WATER-LEVEL DIFFERENCES

| MONTH | NO. POSITIVE VALUES | NO. VALUES OF ZERO DIFFERENCE | NO. NEGATIVE VALUES |
|---|---|---|---|
| FEB 1971 | 280 | 129 | 263 |
| MAR | 254 | 113 | 377 |
| APR | 276 | 218 | 226 |
| MAY | 409 | 183 | 152 |
| JUN | 168 | 182 | 370 |
| JUL | 179 | 276 | 289 |
| AUG | 124 | 280 | 340 |
| SEP | 345 | 196 | 179 |
| OCT | 272 | 168 | 304 |
| NOV | 162 | 163 | 395 |
| DEC | 367 | 98 | 279 |
| JAN 1972 | 374 | 154 | 216 |
| TOTAL | 3210 | 2160 | 3390 |

Figure 3A: SAMPLE OF THE HOURLY WATER-LEVEL DIFFERENCE DATA

Month: June

DATE

| HOUR | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 00 | -0.3 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 | -0.2 | 0.0 |
| 01 | -0.3 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 |
| 02 | -0.3 | -0.2 | -0.1 | -0.2 | -0.1 | 0.0 | -0.1 | 0.0 |
| 03 | -0.2 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | -0.1 | -0.2 |
| 04 | -0.2 | -0.2 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.1 |
| 05 | -0.3 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | -0.1 | 0.0 |
| 06 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 |
| 07 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | -0.1 | -0.1 |
| 08 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 |
| 09 | -0.2 | -0.1 | -0.2 | -0.1 | 0.0 | 0.0 | -0.1 | 0.0 |
| 10 | -0.2 | -0.1 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 |
| 11 | -0.2 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 |
| 12 | -0.2 | -0.1 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 |
| 13 | -0.2 | -0.1 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | 0.0 |
| 14 | -0.2 | -0.1 | -0.2 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 |
| 15 | -0.2 | -0.1 | -0.2 | -0.2 | -0.2 | -0.1 | -0.2 | 0.0 |
| 16 | -0.2 | -0.1 | -0.2 | -0.2 | -0.3 | -0.2 | 0.0 | 0.0 |
| 17 | -0.2 | -0.2 | -0.2 | -0.2 | -0.3 | -0.1 | -0.1 | 0.0 |
| 18 | -0.2 | -0.2 | -0.3 | -0.2 | -0.1 | -0.2 | -0.1 | 0.0 |
| 19 | -0.2 | -0.2 | -0.2 | -0.2 | -0.1 | -0.1 | 0.0 | 0.1 |
| 20 | -0.2 | -0.3 | -0.2 | -0.2 | -0.1 | -0.1 | 0.0 | 0.0 |
| 21 | -0.3 | -0.1 | -0.2 | -0.2 | -0.1 | -0.2 | 0.0 | -0.1 |
| 22 | -0.2 | -0.2 | -0.1 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 |
| 23 | -0.3 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 |

Figure 3B: SAMPLE OF THE FILTERED HOURLY WATER-LEVEL DIFFERENCE DATA

Month: June

DATE

| HOUR | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 00 | -0.3 | -0.2 | | | | | -0.2 | |
| 01 | -0.3 | -0.2 | | | | | | |
| 02 | -0.3 | -0.2 | | -0.2 | | | | |
| 03 | -0.2 | | | | | | | -0.2 |
| 04 | -0.2 | -0.2 | | | | | | |
| 05 | -0.3 | | | | | | | |
| 06 | -0.2 | | | | | | | |
| 07 | -0.2 | | | | | | | |
| 08 | -0.2 | | | | | | | |
| 09 | -0.2 | | -0.2 | | | | | |
| 10 | -0.2 | | -0.2 | -0.2 | | | | |
| 11 | -0.2 | | | | | | | |
| 12 | -0.2 | | -0.2 | -0.2 | | | | |
| 13 | -0.2 | | -0.2 | -0.2 | | | | |
| 14 | -0.2 | | -0.2 | -0.2 | -0.2 | | | |
| 15 | -0.2 | | -0.2 | -0.2 | -0.2 | | -0.2 | |
| 16 | -0.2 | | -0.2 | -0.2 | -0.3 | -0.2 | | |
| 17 | -0.2 | -0.2 | -0.2 | -0.2 | -0.3 | | | |
| 18 | -0.2 | -0.2 | -0.3 | -0.2 | | -0.2 | | |
| 19 | -0.2 | -0.2 | -0.2 | -0.2 | | | | |
| 20 | -0.2 | -0.3 | -0.2 | -0.2 | | | | |
| 21 | -0.3 | | -0.2 | -0.2 | | -0.2 | | |
| 22 | -0.2 | -0.2 | | -0.2 | | | | |
| 23 | -0.3 | -0.2 | -0.2 | | | | | |

TABLE 3: WATER-LEVEL ANOMALIES

Frequency of Occurrence by Month and Duration

TOTAL POSITIVE AND NEGATIVE ANOMALIES

| DURATION (hr) | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-5 | 5 | 8 | 15 | 22 | 16 | 11 | 20 | 16 | 8 | 16 | 3 | 15 | 155 |
| 6-11 | 4 | 5 | 7 | 5 | 5 | 5 | 4 | 4 | 7 | 5 | 5 | 10 | 66 |
| 12-17 | | | 1 | 2 | 2 | 1 | 1 | | 1 | 1 | | 3 | 12 |
| 18-23 | | 3 | | | | | 1 | | | | | 5 | 9 |
| 24-29 | | | | | | | | | | | | | |
| 30-35 | | 1 | | | | | | | | | | | 1 |
| 36-41 | | | 2 | 1 | | | | | | 1 | | 1 | 5 |
| 42-47 | 1 | | | 1 | 1 | | | | | 1 | | | 4 |
| 48-53 | | | | | | | | | | | | | |
| 54-59 | | 1 | | | | | | | | | | | 1 |
| 60-65 | | | | | 1 | | | | | | | 1 | 2 |
| 66-71 | | | | | | | | | | | | | |
| 72-77 | | | | | | | | | | | | | |
| 78-83 | | | | | | | | | | | | | |
| 84-89 | | | | | | | | | 1 | | | | 1 |
| 90-95 | | | | | | | | | | | | | |
| 96-99 | | | | | | | | | | | | | |
| 100-199 | 1 | | | | | | | 1 | 1 | 1 | 1 | | 5 |
| >200 | | 1 | | | | | | | | | 1 | | 2 |
| SUM | 11 | 19 | 25 | 31 | 25 | 17 | 26 | 21 | 18 | 25 | 10 | 35 | 263 |

TABLE 3 (CONTINUED)

POSITIVE ANOMALIES

| DURATION (hr) | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-5 | 1 | 6 | 4 | 19 | 6 | 2 | 4 | 9 | 4 | 6 | | 4 | 65 |
| 6-11 | 1 | 4 | 4 | 4 | | 3 | | 3 | 2 | | 4 | 5 | 30 |
| 12-17 | | | | 2 | | 1 | | | 1 | 1 | | 3 | 8 |
| 18-23 | | 3 | | | | | | | | | | 4 | 7 |
| 24-29 | | | | | | | | | | | | | |
| 30-35 | | 1 | | | | | | | | | | | 1 |
| 36-41 | | | 2 | | | | | | | 1 | | 1 | 4 |
| 42-47 | 1 | | | 1 | | | | | | | | | 2 |
| 48-53 | | | | | | | | | | | | | |
| 54-59 | | | | | | | | | | | | | |
| 60-65 | | | | | 1 | | | | | | | 1 | 2 |
| 66-71 | | | | | | | | | | | | | |
| 72-77 | | | | | | | | | | | | | |
| 78-83 | | | | | | | | | | | | | |
| 84-89 | | | | | | | | | | | | | |
| 90-95 | | | | | | | | | | | | | |
| 96-99 | | | | | | | | | | | | | |
| 100-199 | 1 | | | | | | | 1 | 1 | | 1 | | 4 |
| > 200 | | | | | | | | | | | | | |
| SUM | 4 | 14 | 10 | 26 | 7 | 6 | 4 | 13 | 8 | 8 | 5 | 18 | 123 |

TABLE 3 (CONTINUED)

NEGATIVE ANOMALIES

| DURATION (hr) | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-5 | 4 | 2 | 11 | 3 | 10 | 9 | 16 | 7 | 4 | 10 | 3 | 11 | 90 |
| 6-11 | 3 | 1 | 3 | 1 | 5 | 2 | 4 | 1 | 5 | 5 | 1 | 5 | 36 |
| 12-17 | | | 1 | | 2 | | 1 | | | | | | 4 |
| 18-23 | | | | | | | 1 | | | | | 1 | 2 |
| 24-29 | | | | | | | | | | | | | |
| 30-35 | | | | | | | | | | | | | |
| 36-41 | | | | 1 | | | | | | | | | 1 |
| 42-47 | | | | | 1 | | | | | 1 | | | 2 |
| 48-53 | | | | | | | | | | | | | |
| 54-59 | | 1 | | | | | | | | | | | 1 |
| 60-65 | | | | | | | | | | | | | |
| 66-71 | | | | | | | | | | | | | |
| 72-77 | | | | | | | | | | | | | |
| 78-83 | | | | | | | | | | | | | |
| 84-89 | | | | | | | | | 1 | | | | 1 |
| 90-95 | | | | | | | | | | | | | |
| 96-99 | | | | | | | | | | | | | |
| 100-199 | | | | | | | | | | 1 | | | 1 |
| >200 | | 1 | | | | | | | | | 1 | | 2 |
| SUM | 7 | 5 | 15 | 5 | 18 | 11 | 22 | 8 | 10 | 17 | 5 | 17 | 140 |

TABLE 4: EXTREME WATER-LEVEL ANOMALIES

Frequency of Occurrence by Month and Duration

TOTAL POSITIVE AND NEGATIVE ANOMALIES

| DURATION (hr) | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-5 | 5 | 9 | 2 | 1 | 1 | 1 | | 6 | 1 | 3 | 5 | 2 | 36 |
| 6-11 | 1 | 4 | 1 | | | | | 1 | | 1 | 1 | 2 | 11 |
| 12-17 | | | | 1 | | | | | 1 | | 2 | 1 | 5 |
| 18-23 | | 1 | | | | | | | | | 2 | | 3 |
| 24-29 | | | | | | | | | | 1 | 1 | | 2 |
| 30-35 | 1 | | | | | | | | | | | | 1 |
| 36-41 | | | | | | | | | | | | | |
| 42-47 | | | | | | | | | | | | | |
| 48-53 | | | | | | | | | | | | | |
| 54-59 | | 1 | | | | | | | | | | | 1 |
| 60-65 | 1 | | | | | | | | | | | | 1 |
| >100 | | | | | | | | | | | 1 | | 1 |
| SUM | 8 | 15 | 3 | 2 | 1 | 1 | 0 | 7 | 2 | 5 | 12 | 5 | 61 |

TABLE 4 (CONTINUED)

POSITIVE ANOMALIES

| DURATION (hr) | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-5 | 4 | 5 | 2 | | 1 | | | 6 | 1 | 1 | 1 | 1 | 22 |
| 6-11 | 1 | 1 | 1 | | | | | 1 | | 1 | | 2 | 7 |
| 12-17 | | | | 1 | | | | | | | | 1 | 2 |
| 18-23 | | | | | | | | | | | | | |
| 24-29 | | | | | | | | | | | 1 | | 1 |
| 30-35 | 1 | | | | | | | | | | | | 1 |
| >100 | | | | | | | | | | | 1 | | 1 |
| SUM | 6 | 6 | 3 | 1 | 1 | 0 | 0 | 7 | 1 | 2 | 3 | 4 | 34 |

NEGATIVE ANOMALIES

| DURATION (hr) | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-5 | 1 | 4 | | 1 | | 1 | | | | 2 | 4 | 1 | 14 |
| 6-11 | | 3 | | | | | | | | | 1 | | 4 |
| 12-17 | | | | | | | | | 1 | | 2 | | 3 |
| 18-23 | | 1 | | | | | | | | | 2 | | 3 |
| 24-29 | | | | | | | | | | 1 | | | 1 |
| 54-59 | | 1 | | | | | | | | | | | 1 |
| 60-65 | 1 | | | | | | | | | | | | 1 |
| SUM | 2 | 9 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 3 | 9 | 1 | 27 |

# IV. RELATIONSHIP OF WATER-LEVEL DEVIATIONS TO ATMOSPHERIC PRESSURE

## A. INTRODUCTION

Water-level variations observed on the Pacific Coast which are considered to have been caused by meteorological or oceanographic processes have been studied by several investigators. Jacobs (1939) related changes in mean monthly sea level at four California tide stations to wind-driven water transport along the Pacific Coast; the wind-driven system, he concluded, was directly controlled by the development of the North Pacific high pressure cell. He doubted that the meteorological factor(s) responsible for short-period local water-level deviations could be isolated. Armstrong (1958) investigated the correlation between the average monthly sea level and the average monthly atmospheric pressure at five tide stations on the Canadian Pacific Coast; he discovered that the sea-level response was greater than theoretically predicted and concluded that both wind-stress and atmospheric pressure changes were responsible for the observed deviations in the monthly mean sea level. O'Connor (1964), in investigating short-period water-level deviations at Monterey, concluded that variations in atmospheric pressure masked all but the strongest wind effects but he was unable to discover any clear relationship.

In the present study, in order to identify the causes of the observed water-level anomalies, attention was directed to those factors having similar durations. Accordingly, the following factors were examined on an hourly basis in relation to the water-level anomalies studied:

1. Wind speed and direction recorded at two locations considered to be reasonably representative of the local winds over Monterey Bay:

a. Naval Air Facility, Monterey; wind data recorded hourly.

b. Pacific Gas and Electric Company Power Plant, Moss Landing, California; wind data recorded every two minutes and averaged over the period of an hour. The anemometer was located at a height of 225 feet above the ground.

2. Sea-level pressure recorded continuously at the Naval Postgraduate School.

3. Sea-Surface temperature recorded on Monterey Municipal Wharf No. 2.

From a comparison of these parameters with the water-level anomalies studied, a close association was evident to the atmospheric pressure, but no relationship could be observed to wind velocity or to water temperature. The effects of wind stress on the water level were anticipated; a possible explanation for the absence of a water-level response to the wind is that the tide-gage location is sheltered behind the Monterey Peninsula from the prevailing westerly onshore wind directions (SW to NW).

The fact that the continental shelf is narrow and the water is relatively deep close to shore undoubtedly greatly minimizes the wind setup compared to that observed on coasts off which the shelf is broad and shallow near shore.

In view of the close association observed between water-level variations and atmospheric pressure, this relationship was examined in detail. Three approaches were taken:

1. Determination of the statistical relationship between time-coincident values of water-level difference and atmospheric pressure at a six-hourly sampling interval.

2. Examination of the atmospheric pressure variation associated with the observed water-level anomalies.

3. Examination of the synoptic weather situations associated with water-level anomalies.

## B. STATISTICAL RELATIONSHIP BETWEEN ATMOSPHERIC PRESSURE AND WATER-LEVEL DIFFERENCE

The atmospheric pressure prevailing at Monterey was extracted from the National Weather Service surface analysis charts prepared daily at 0000, 0600, 1200, 1800 GMT. Fourteen hundred six-hourly pressure values out of the 1460 charts covering the year selected were obtained since not all of the charts were of sufficient clarity for use. The pressure value was taken from the Monterey station report.

The six-hourly pressure values were subjected to a standard regression analysis with those hourly water-level difference values occurring at the same time. The results of the analysis, conducted by months and over the year considered in the study, are presented in Figures 4 through 16. The numbers in each figure indicate the number of occurrences of each combination of atmospheric pressure and water-level difference indicated by the coordinates.

The results of the regression analysis, including the arithmetic means of atmospheric pressure and water-level difference, are summarized in Table 5. The slopes of the regression lines principally fall in the range -0.018 to -0.038 ft/mb, with only three months lying outside this range. The sum of the squares indicates the spread of the data points; it may be seen that the regression-line fit is generally poorer in the winter months. It may also be noted that the intercept of the regression lines with zero water-level difference generally coincides closely

with the mean monthly atmospheric pressure. The pressure corresponding to the regression-line intercept with zero water-level difference is that pressure considered to be statistically least likely to have caused a water-level deviation.

Figure 17 shows graphically the monthly values of the mean atmospheric pressure and the pressure corresponding to the regression-line intercept, along with a long-term mean pressure at Monterey for comparison. The latter values were obtained from monthly mean surface pressure charts of the northern hemisphere over the five-year period 1963-1968 (Hesse and Stevenson, 1968). It may be noted that all three mean pressures display the same general trend of lower pressure during the summer months and higher pressure during the winter months.

The theoretical response of water level to changes of atmospheric pressure equals a water-level change of $\pm 0.1$ foot for $\mp 3$ millibars of pressure change; the slope of this linear relationship is -0.033 ft/mb. It may be concluded from the regression-line slopes listed in Table 5, that the water level at Monterey responds to a change in atmospheric pressure in an approximately hydrostatic manner.

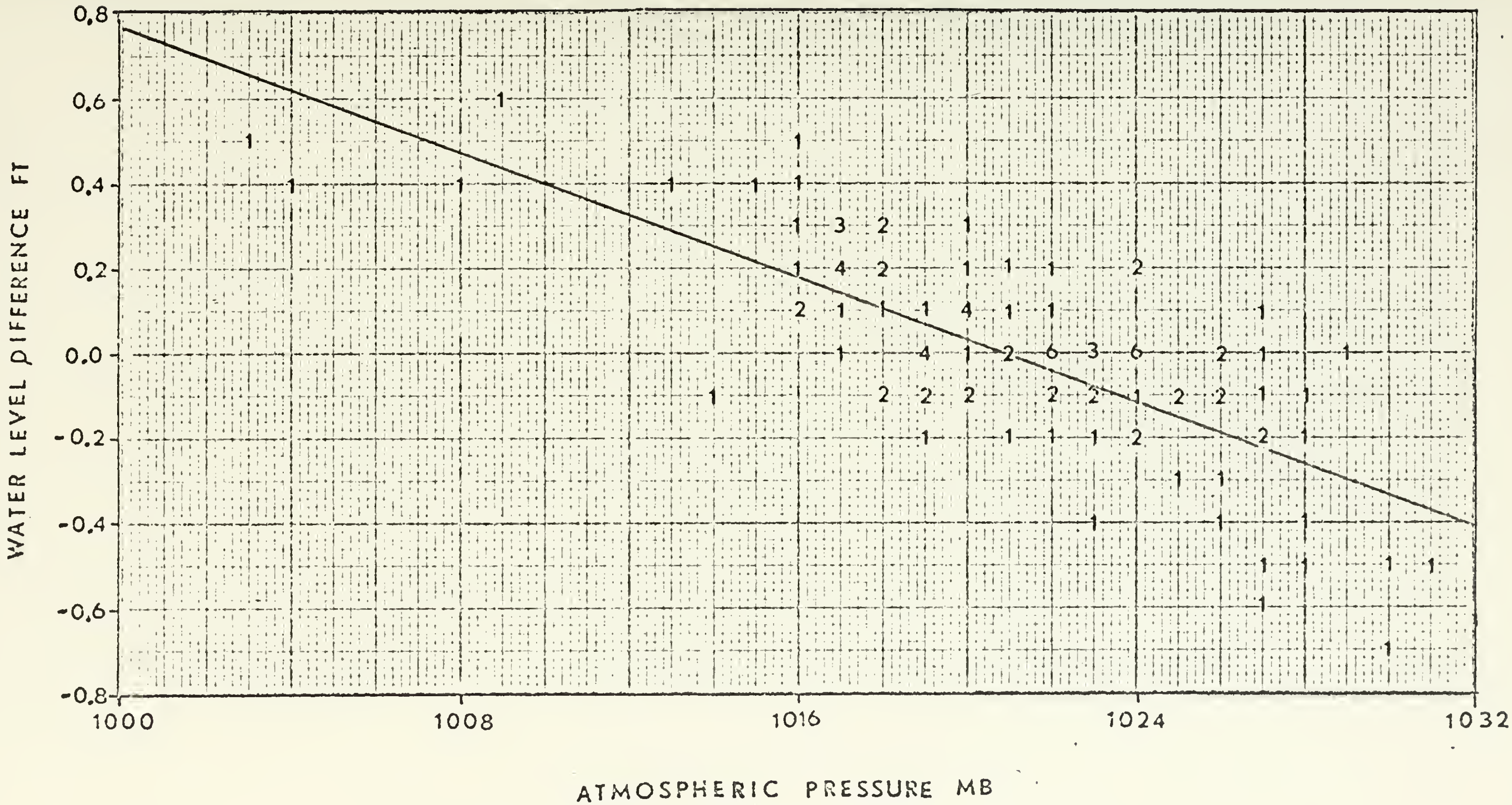


FIGURE 4: REGRESSION ANALYSIS - FEBRUARY 1971

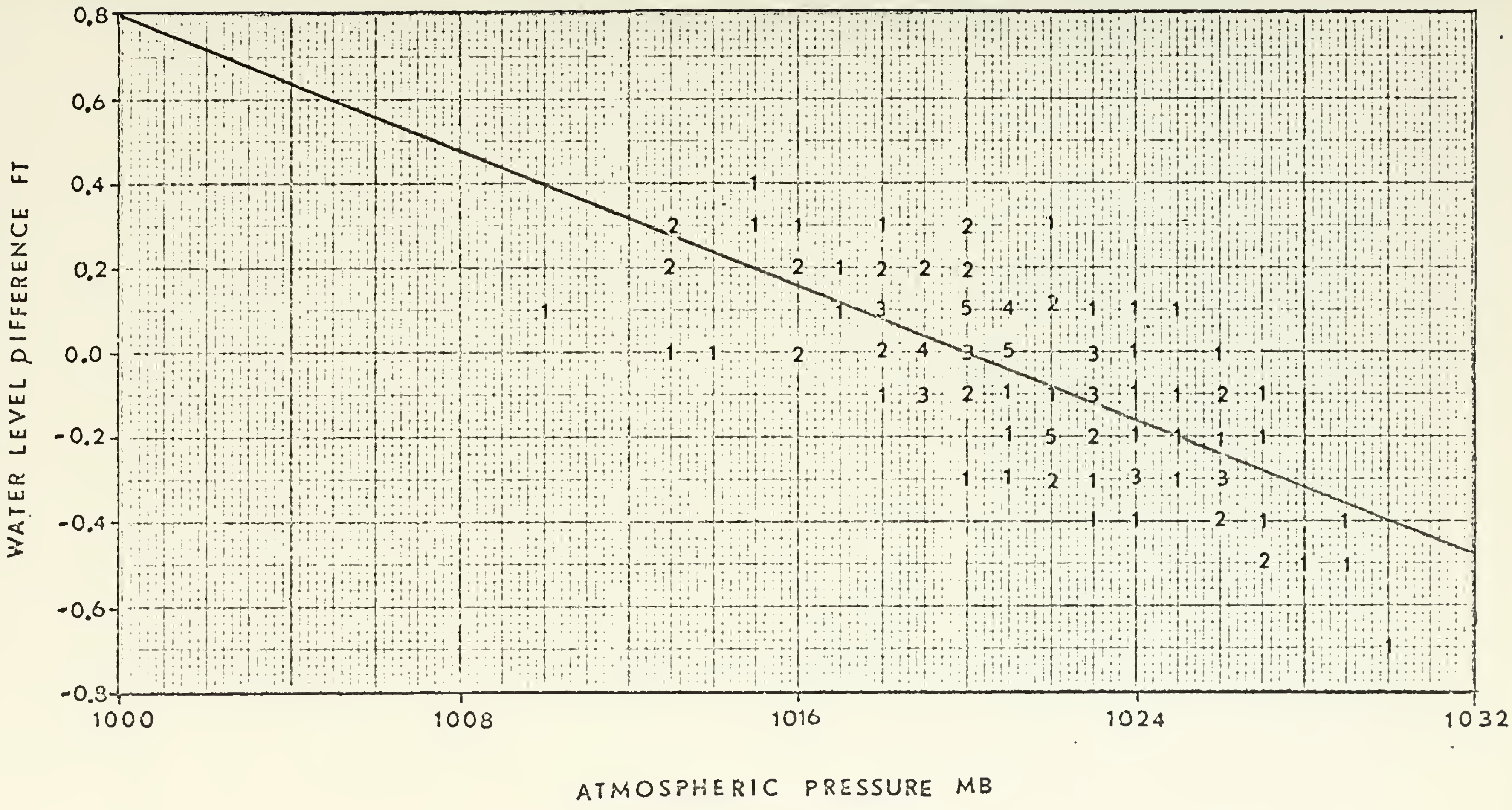


FIGURE 5: REGRESSION ANALYSIS - MARCH 1971

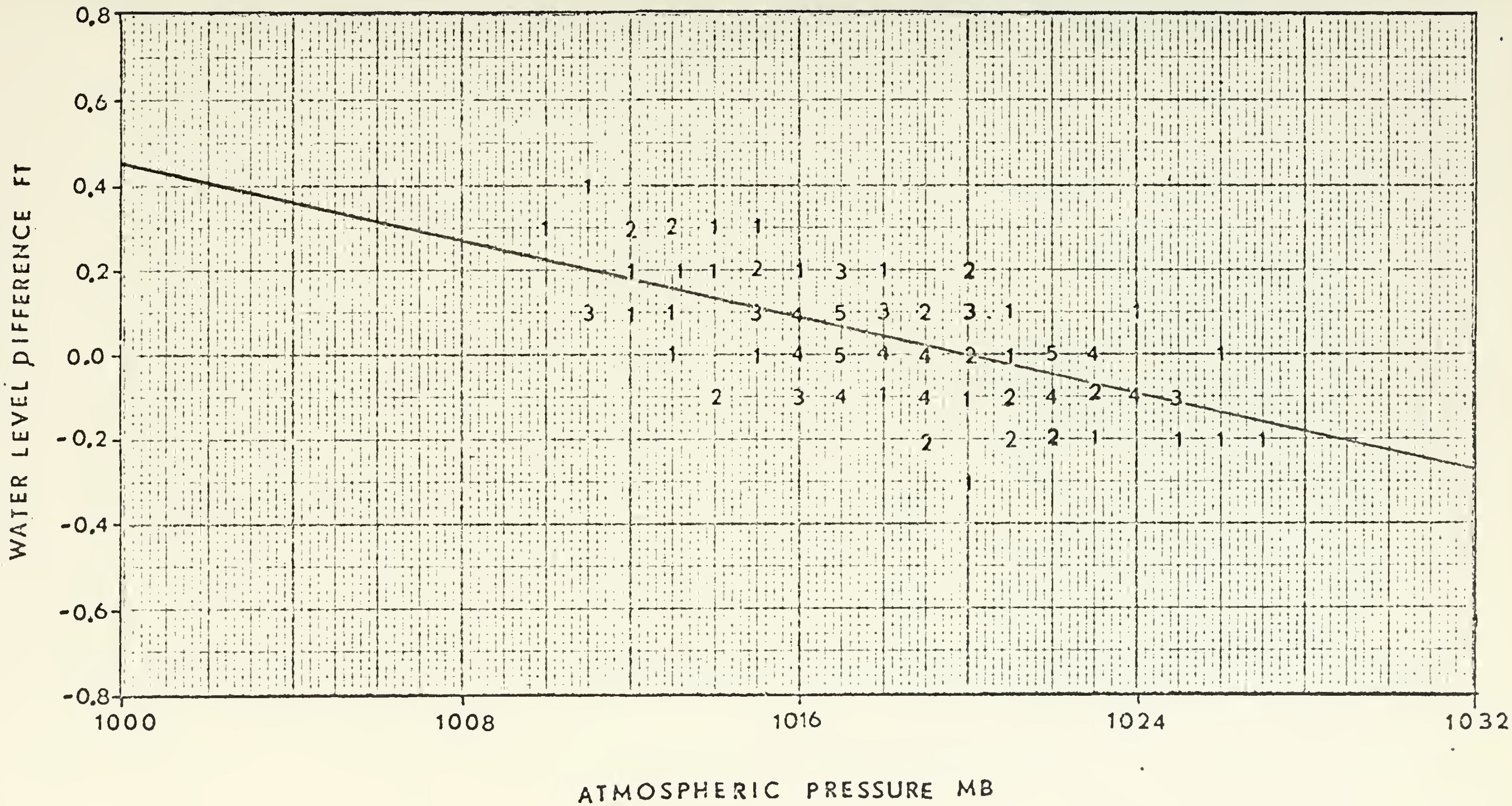


FIGURE 6: REGRESSION ANALYSIS - APRIL 1971

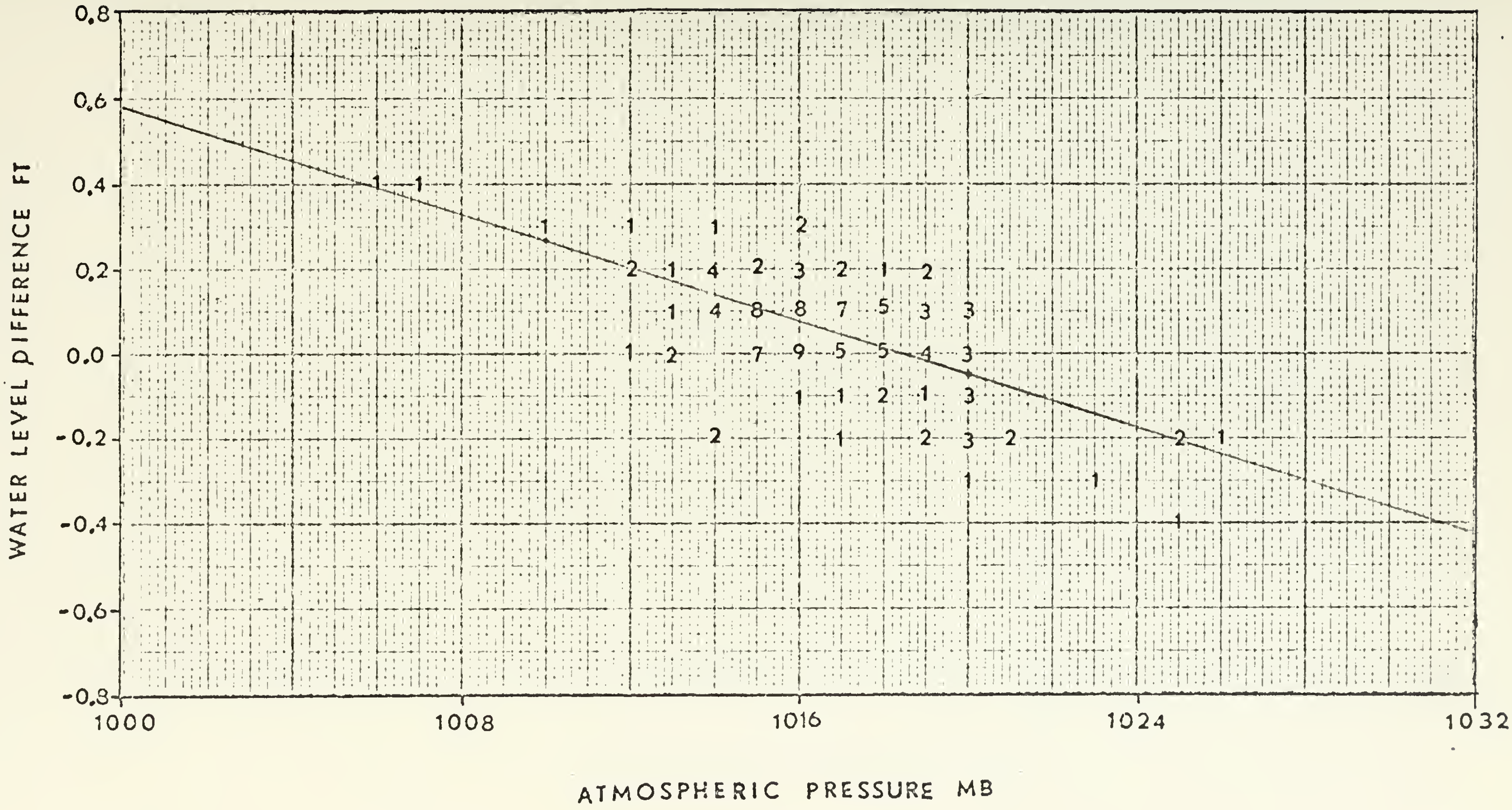


FIGURE 7 : REGRESSION ANALYSIS - MAY 1971

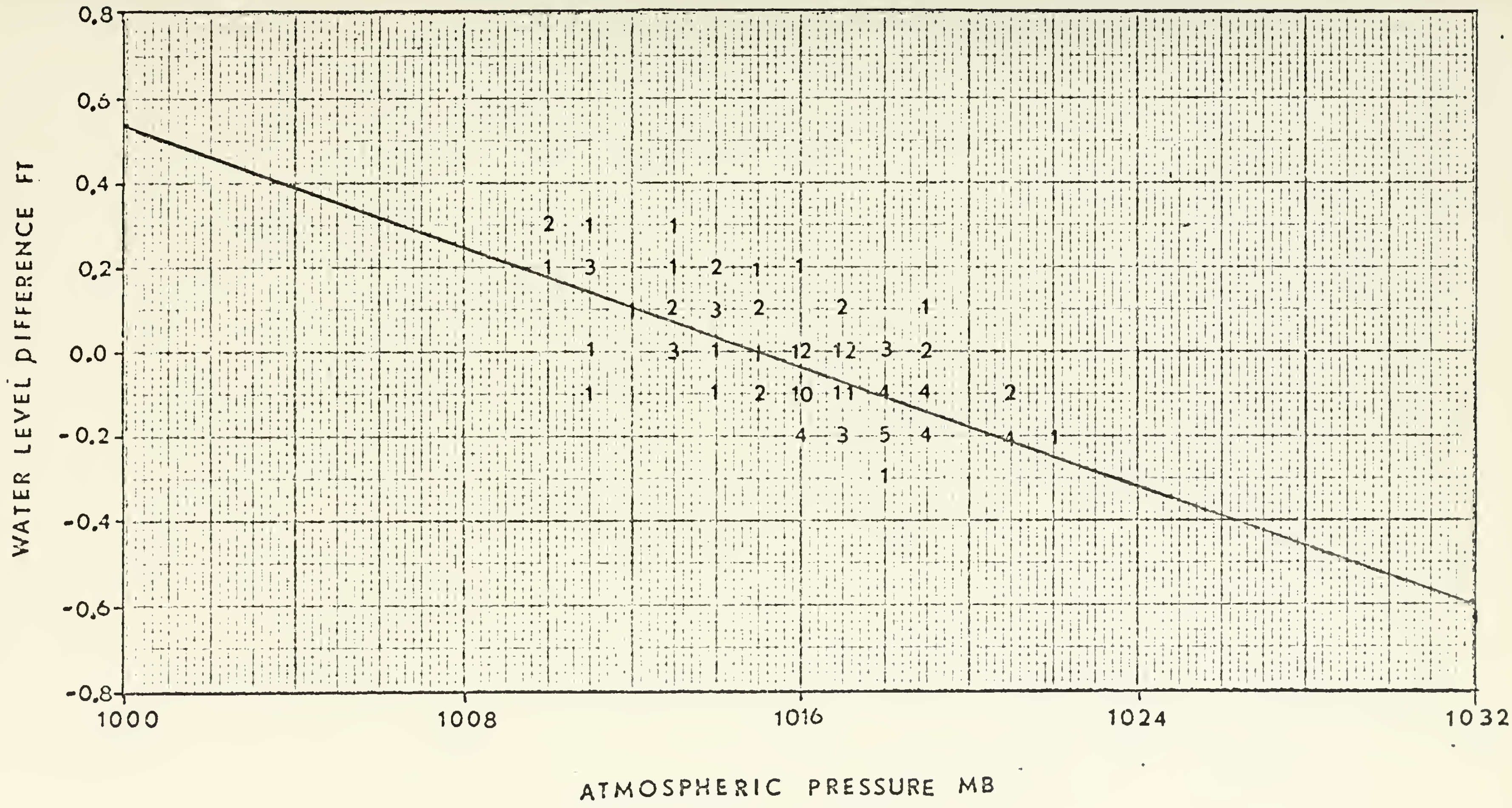


FIGURE 8: REGRESSION ANALYSIS - JUNE 1971

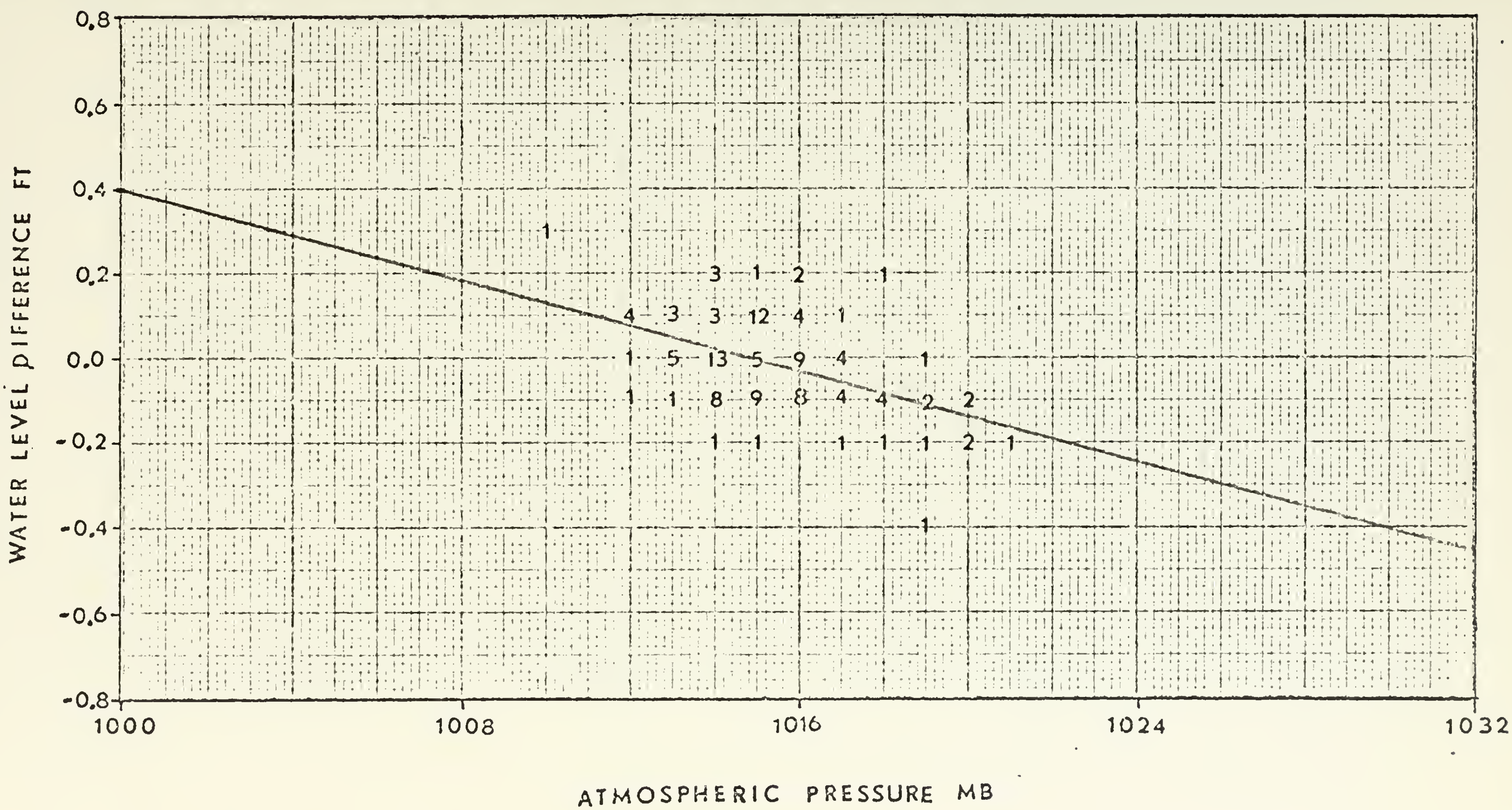


FIGURE 9: REGRESSION ANALYSIS - JULY 1971

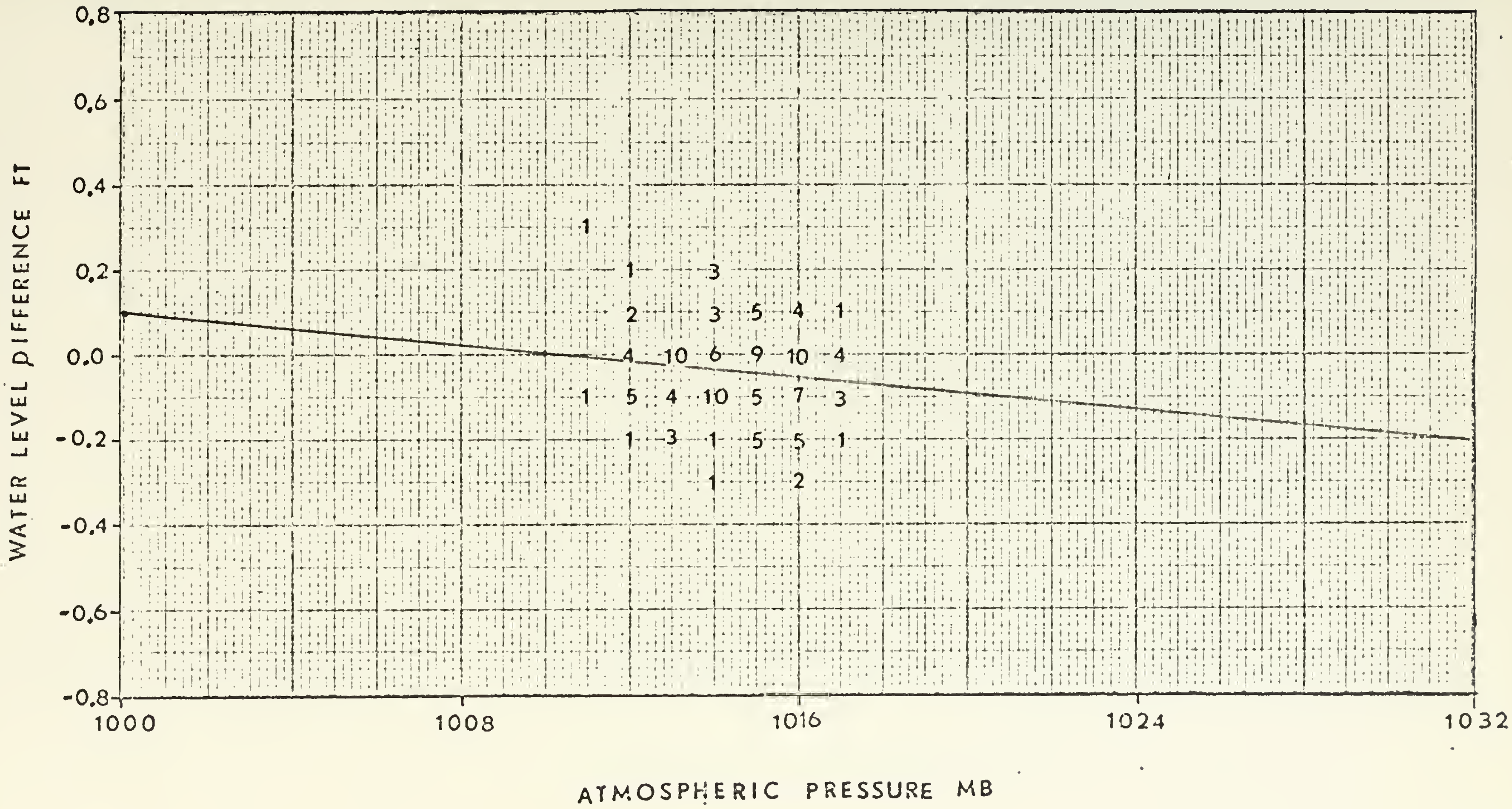


FIGURE 10: REGRESSION ANALYSIS - AUGUST 1971

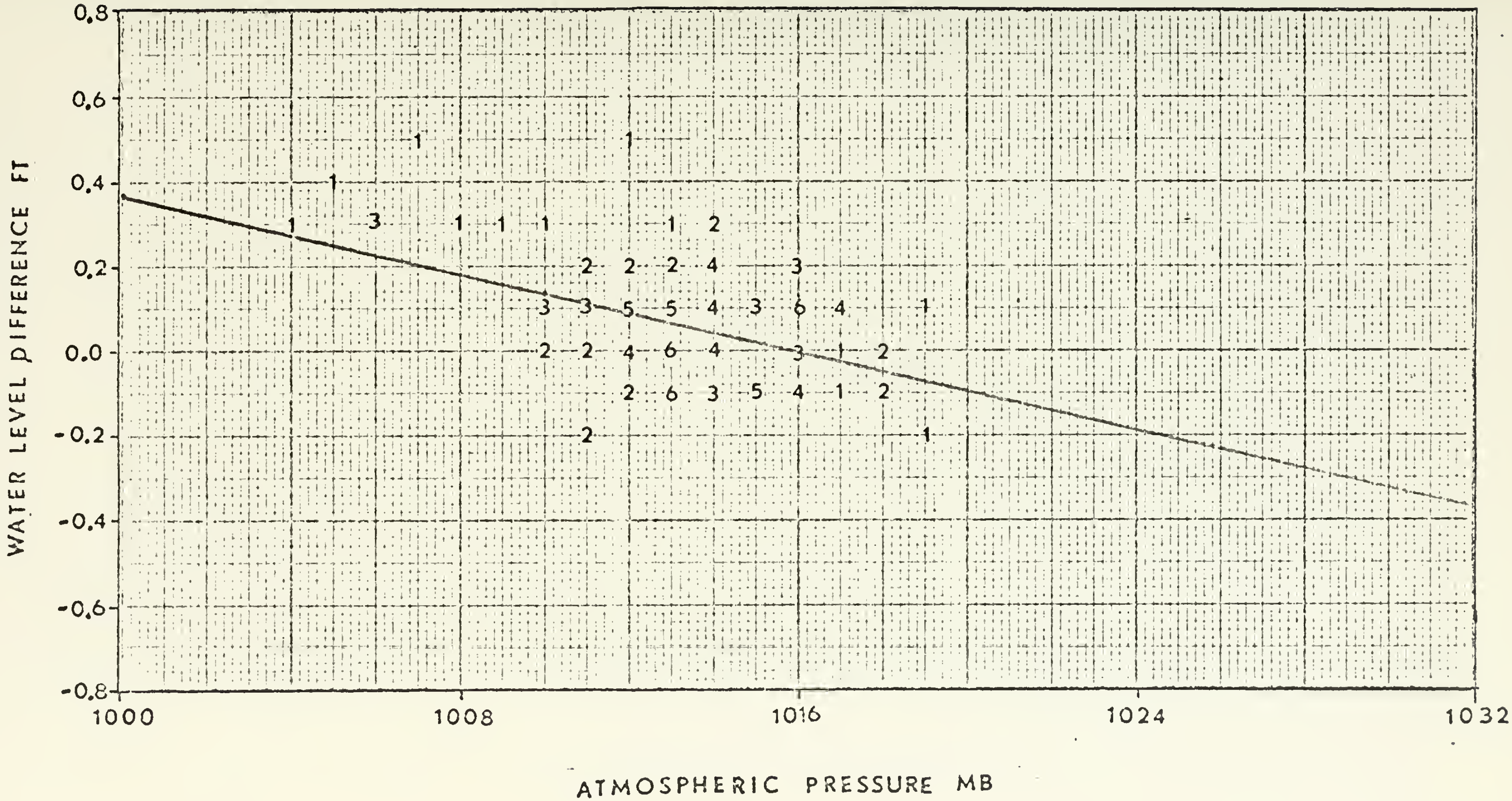


FIGURE 11: REGRESSION ANALYSIS - SEPTEMBER 1971

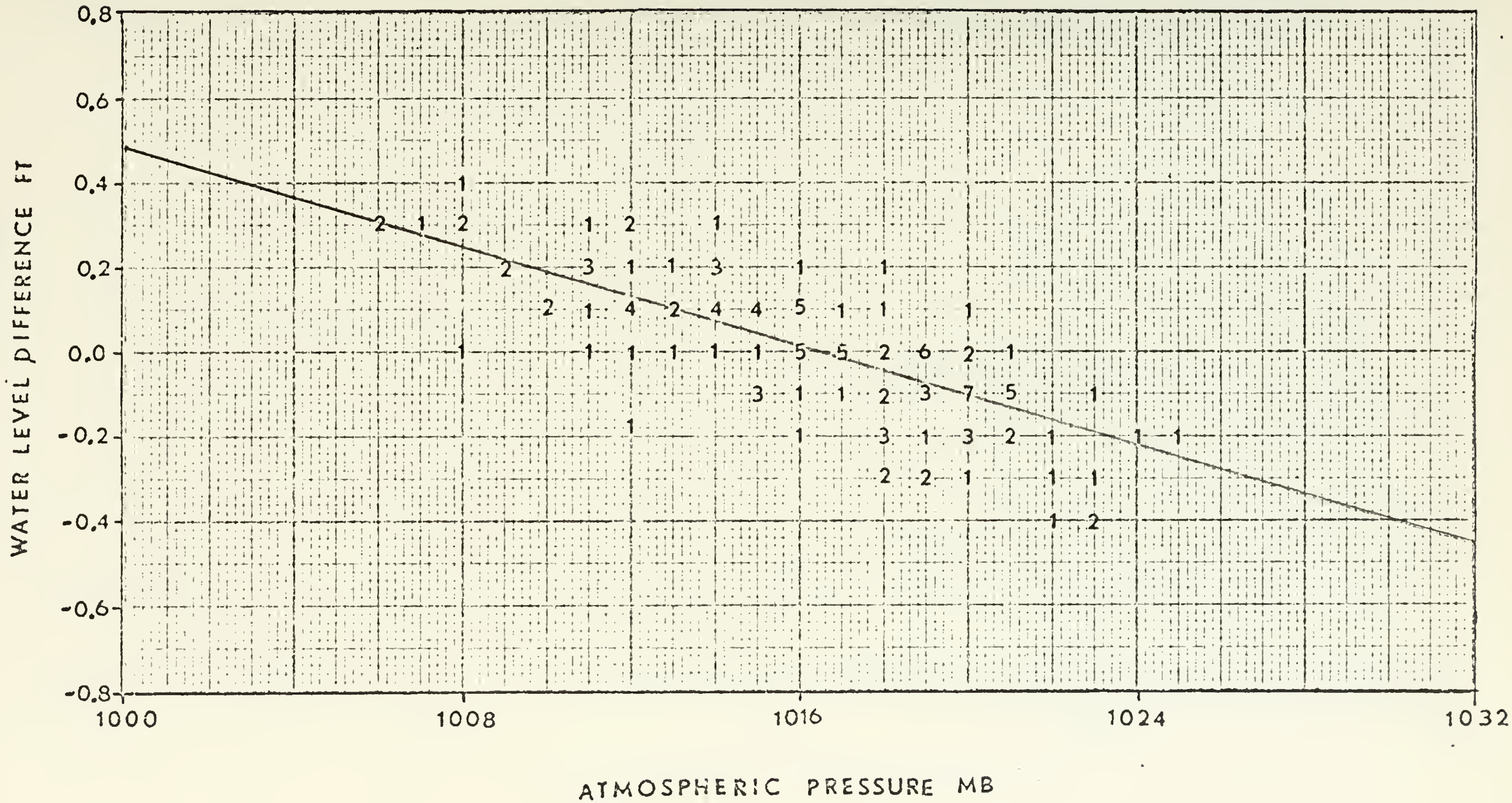


FIGURE 12: REGRESSION ANALYSIS - OCTOBER 1971

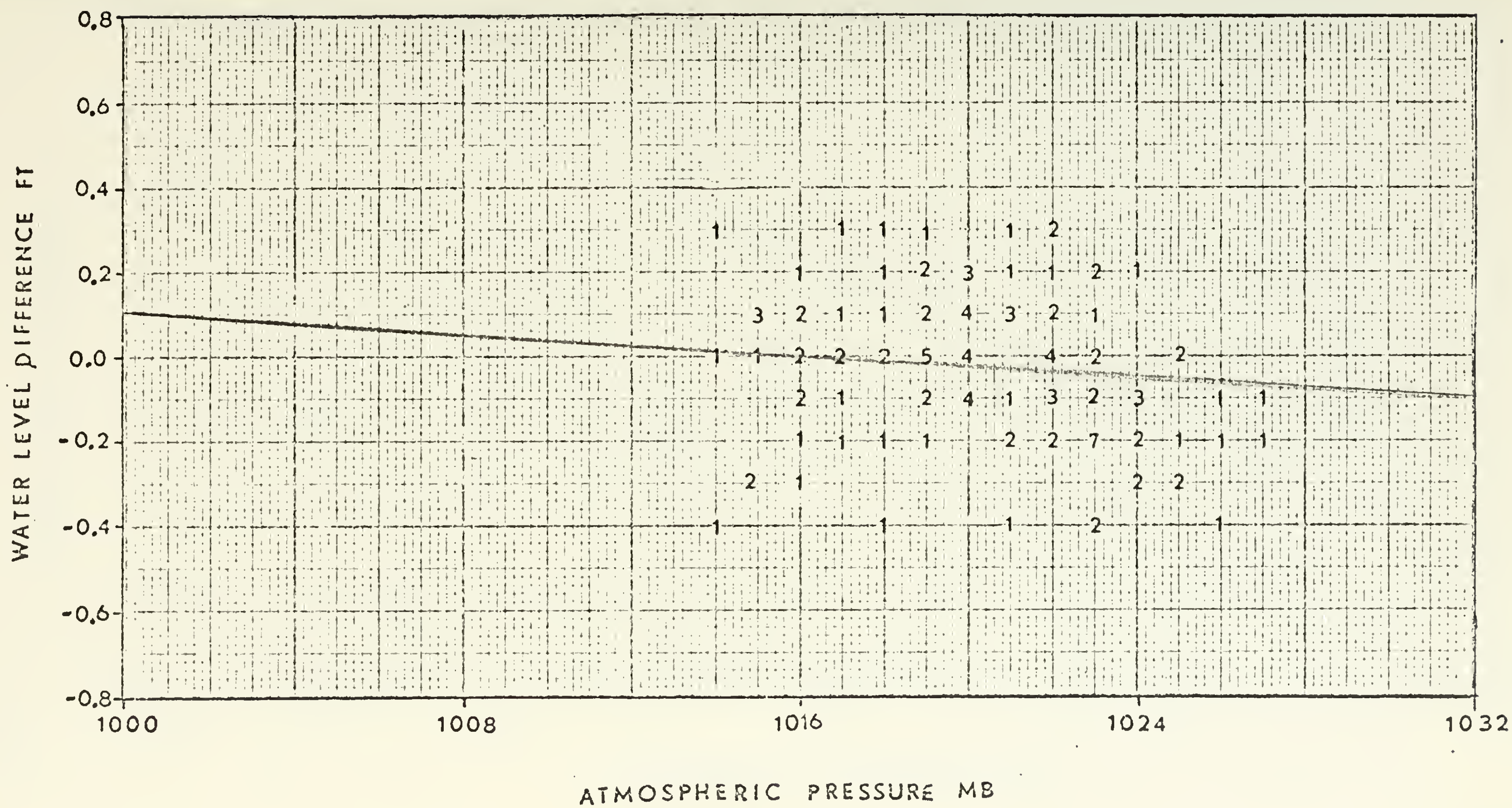


FIGURE 13: REGRESSION ANALYSIS - NOVEMBER 1971

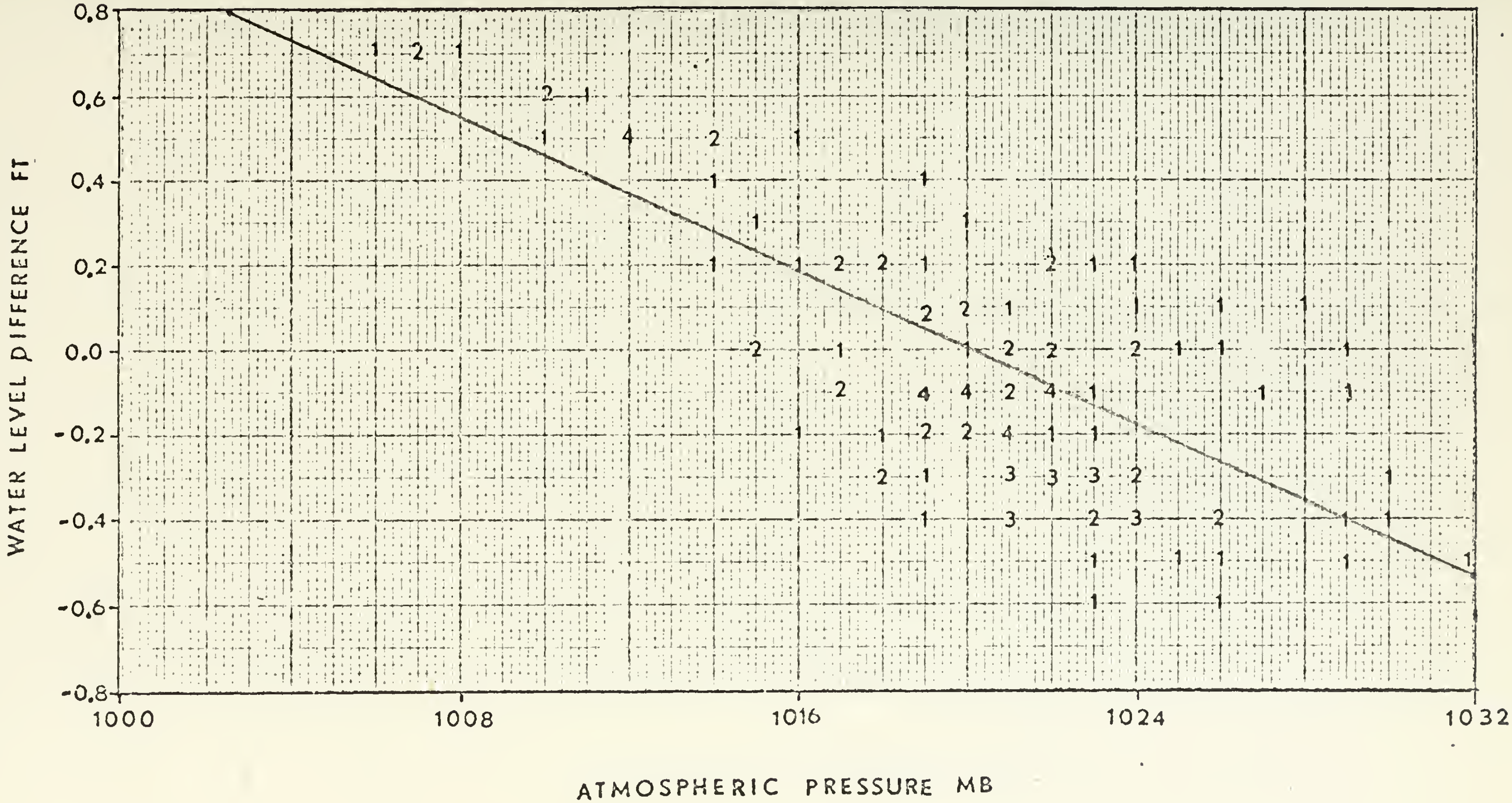


FIGURE 14: REGRESSION ANALYSIS - DECEMBER 1971

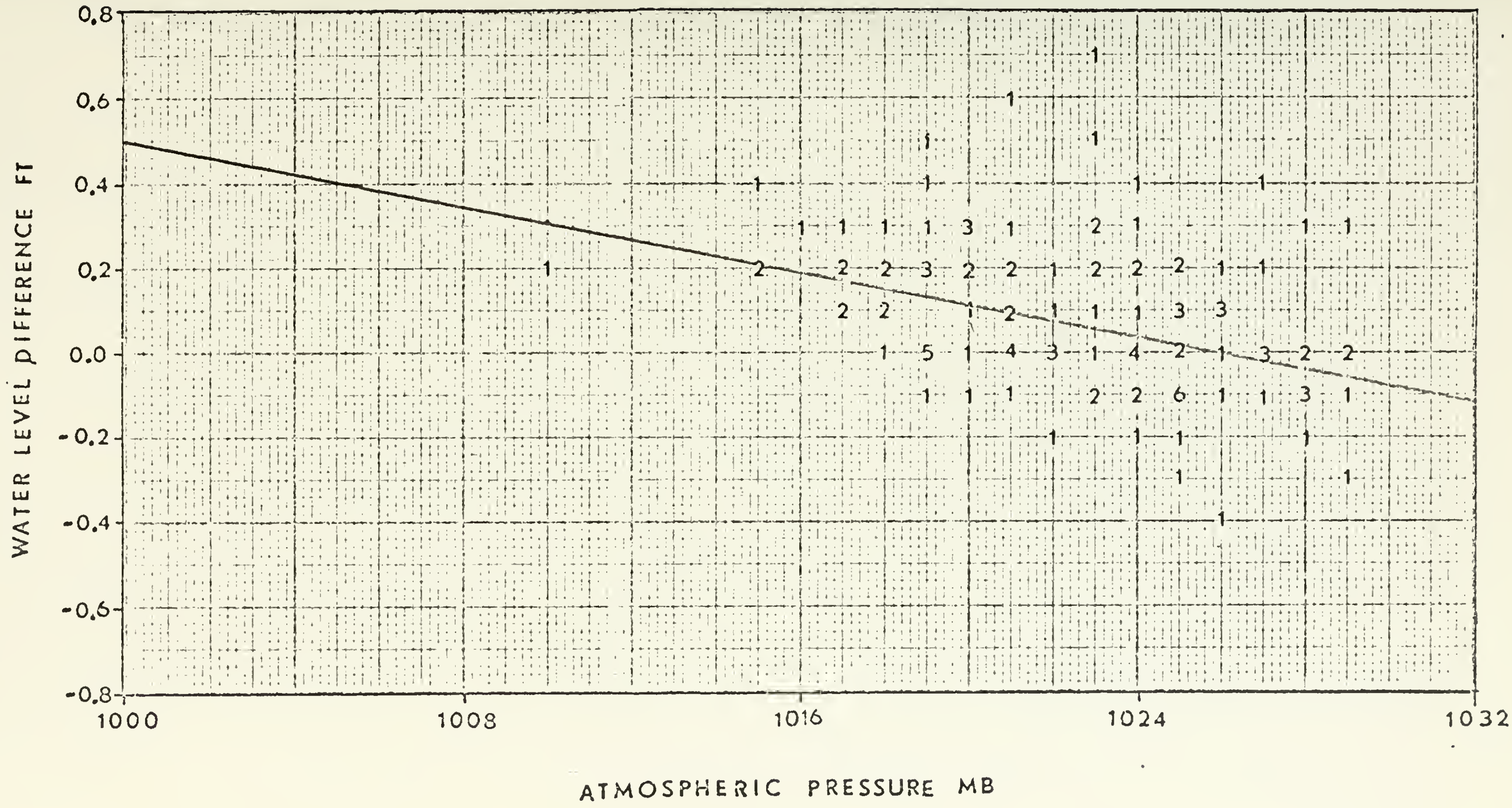


FIGURE 15: REGRESSION ANALYSIS - JANUARY 1972

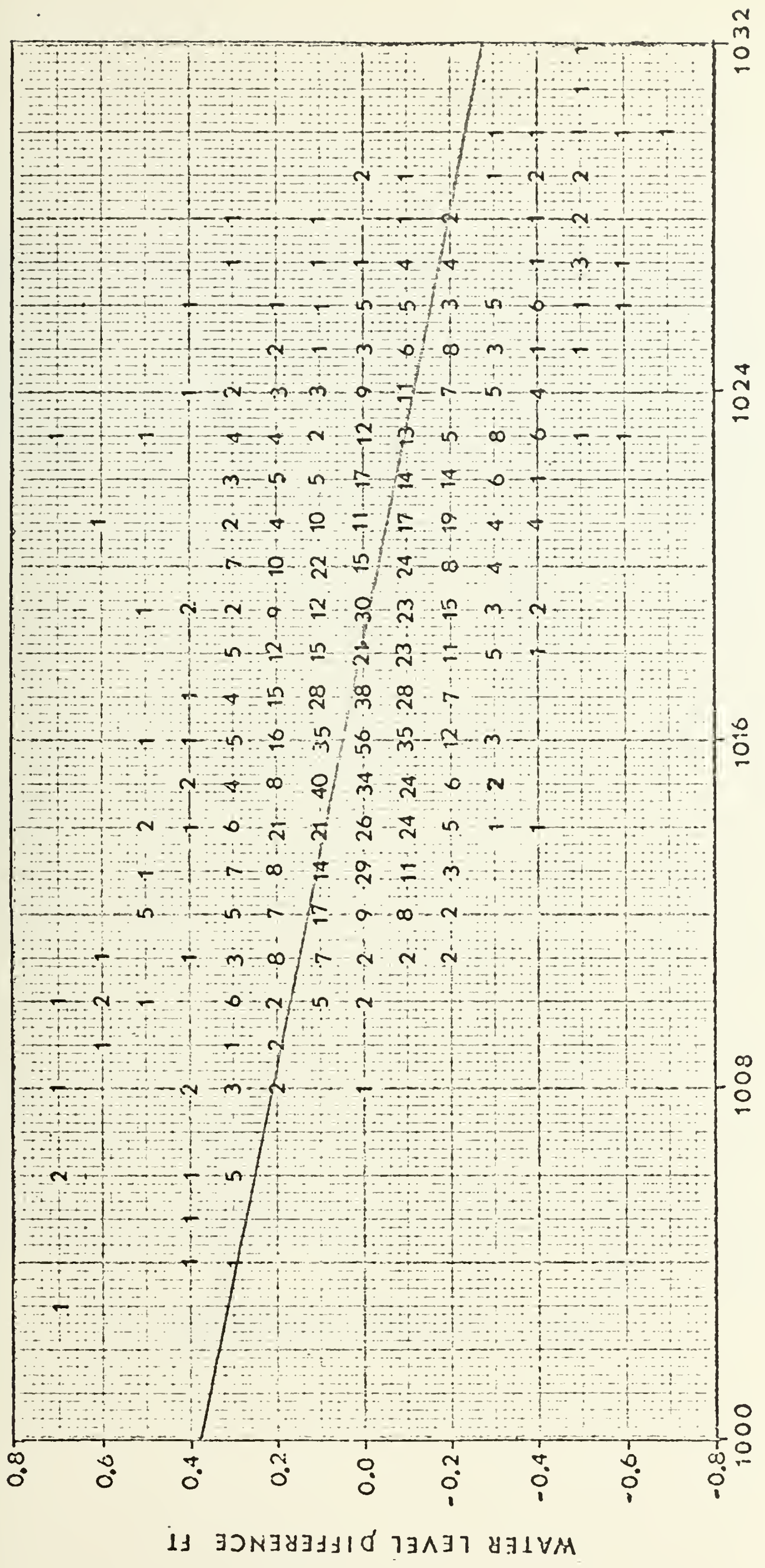


FIGURE 16: REGRESSION ANALYSIS - YEAR (FEB 1971 - JAN 1972)

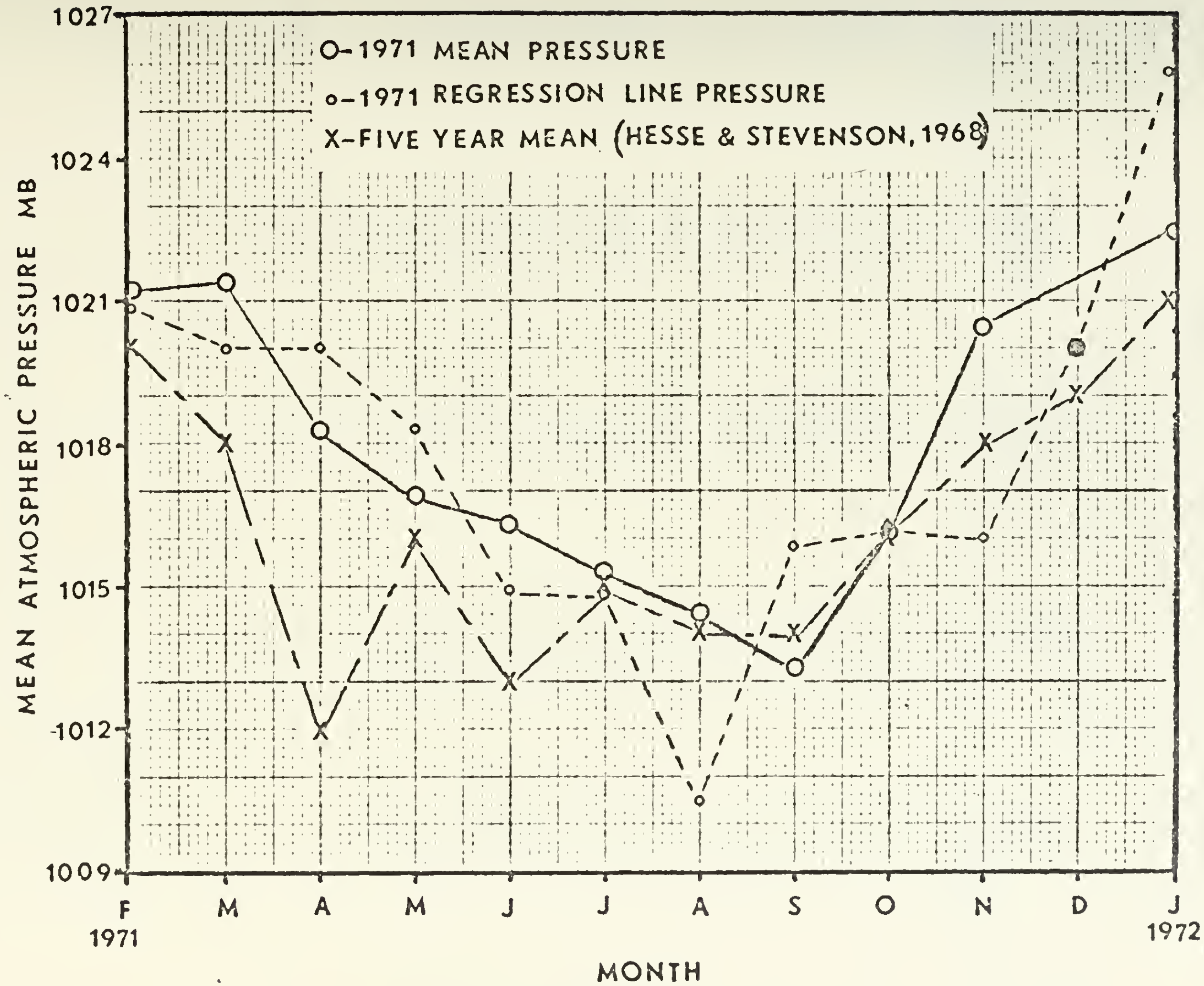


FIGURE 17: MONTHLY ATMOSPHERIC PRESSURES AT MONTEREY, CALIFORNIA

TABLE 5: REGRESSION ANALYSIS SUMMARY

| MONTH | MEAN PRESSURE (mb) | MEAN WATER LEVEL DIFFERENCE (feet) | REGRESSION LINE SLOPE (ft/mb) | SUM OF SQUARES | REGRESSION LINE INTERCEPT (mb) |
|---|---|---|---|---|---|
| FEB 1971 | 1021.2 | 0.000 | -0.035 | 2.41 | 1020.8 |
| MAR | 1021.4 | -0.054 | -0.038 | 2.58 | 1020.0 |
| APR | 1018.3 | 0.018 | -0.023 | 1.36 | 1020.0 |
| MAY | 1016.9 | 0.048 | -0.032 | 1.16 | 1018.3 |
| JUN | 1016.3 | 0.037 | -0.035 | 1.13 | 1014.9 |
| JUL | 1015.3 | -0.009 | -0.027 | 1.16 | 1014.8 |
| AUG | 1014.5 | -0.041 | -0.010 | 1.46 | 1010.5 |
| SEP | 1013.3 | 0.066 | -0.023 | 1.79 | 1015.8 |
| OCT | 1016.1 | -0.002 | -0.029 | 1.62 | 1016.4 |
| NOV | 1020.5 | -0.001 | -0.006 | 3.25 | 1016.0 |
| DEC | 1020.0 | -0.005 | -0.047 | 6.27 | 1020.0 |
| JAN 1972 | 1022.5 | 0.092 | -0.018 | 3.46 | 1025.8 |
| YEAR | 1018.0 | 0.006 | -0.019 | 39.84 | 1018.2 |

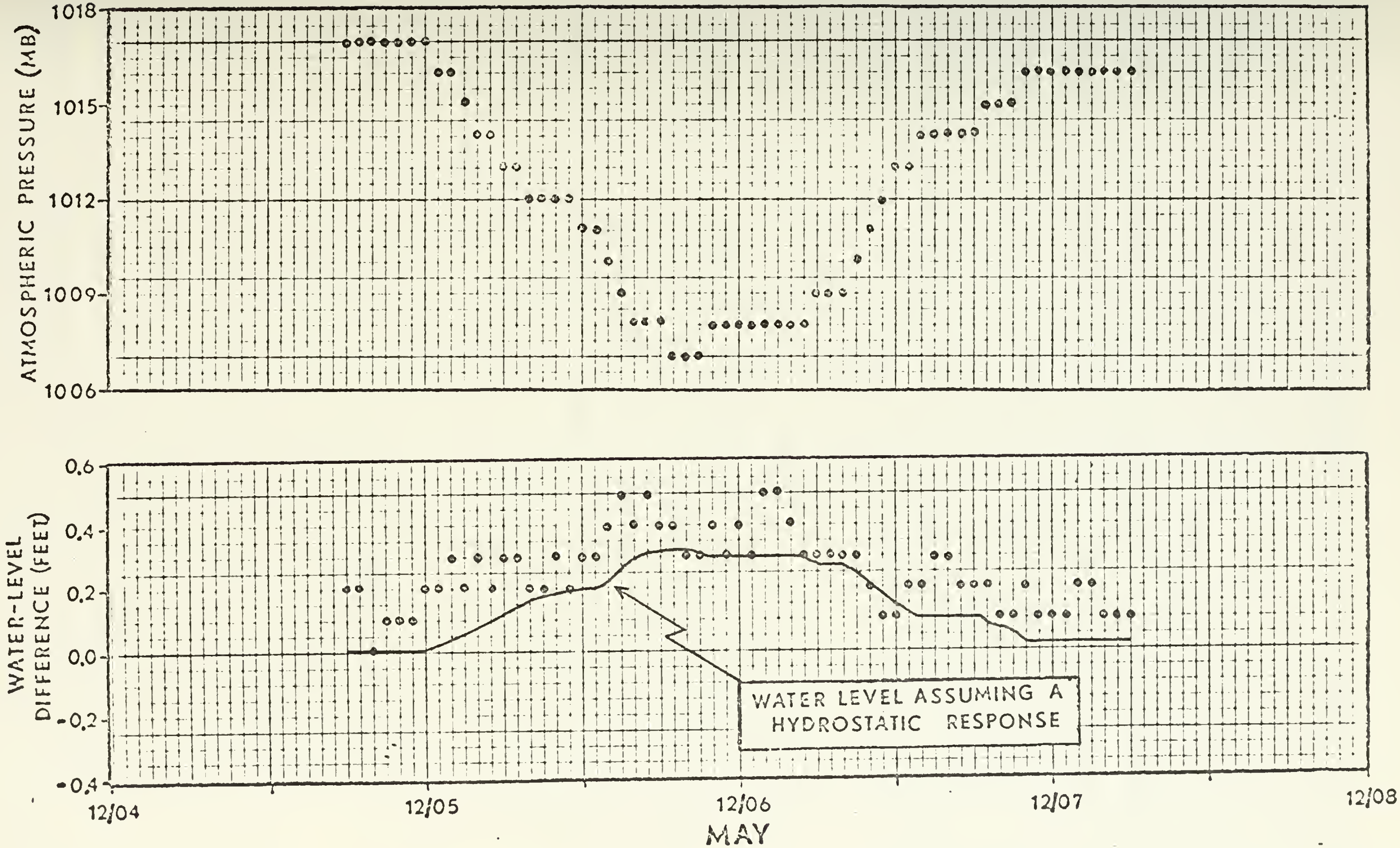


FIGURE 18: WATER-LEVEL ANOMALY AND ASSOCIATED PRESSURE DISTRIBUTION

## C. ATMOSPHERIC PRESSURE VARIATIONS ASSOCIATED WITH WATER-LEVEL ANOMALIES.

The large number of water-level anomalies occurring during the year (263) were reduced to an amenable number by focusing attention on those anomalies having a duration of twelve hours or greater. This lowered the number to be investigated to 42 (Appendix B). In the investigation of the effect of variations of atmospheric pressure in producing anomalies, the distribution of hourly sea-level pressures at Monterey was compared with the hourly water-level differences comprising each anomaly. The hourly pressures were obtained from a standard barograph at Monterey; they agreed with the six-hourly values described in the previous section which were obtained from weather charts.

An example of a water-level anomaly and the associated pressure distribution is displayed in Figure 18. The smooth curve shown in the figure represents the water-level variation derived from the pressure distribution assuming a hydrostatic response; the water-level at the beginning of the anomaly is considered to be adjusted to the initial pressure. It may be noted that the hourly water-level differences show the same trend as the hourly pressure values with almost no lag in response. The water level appeared to over respond during the rapid drop in pressure at the onset of the pressure change, but during the period of rising pressure, responded very nearly in a hydrostatic manner.

The degree of response of the water level to an atmospheric pressure change can be expected to be a function of the rate of change of pressure. When the pressure change occurs slowly full hydrostatic response should be expected; however, with a rapid pressure change the amplitude of the water-level anomaly produced should be less than that expected hydrostatically, and the time of the water-level peak (maxima or minima) should lag behind that of the pressure peak.

Of the 42 water-level anomalies examined, all but one were found to respond to a variation in atmospheric pressure such that an increase (decrease) in atmospheric pressure produced a negative (positive) water-level anomaly. The one exception occurred beginning on 29 November. In response to slow changes of pressure, the water-level exhibited little or no time lag, but the lag was variable and generally amounted to one to three hours with rapid pressure changes of large magnitude. The amplitude response of the water level anomaly was nearly hydrostatic with respect to the imposed pressure.

## D. SYNOPTIC WEATHER EVENTS ASSOCIATED WITH ANOMALIES

Having noted the association of atmospheric pressure variations and water-level anomalies, the National Weather Service six-hourly surface analysis charts were examined to determine if these pressure variations could be related to synoptic weather situations. This examination was performed by comparing the isobaric patterns on each of the six-hourly charts of each month with the long-term mean monthly pressure pattern for the northern hemisphere compiled by Hesse and Stevenson (1968).

The North Pacific high-pressure cell and the predominant low pressure cell or trough extending northward over Mexico and the southwestern United States are characteristic features of the long-term surface pressure distribution throughout the year, although they vary in intensity and location with the seasons. These climatic features may be seen in Figures 19 and 21. It was found that the intensification or displacement toward Monterey of either of these features was directly related to the atmospheric pressure changes which caused the majority of the observed water-level anomalies.

Examples of the two types of synoptic situations found to be responsible for 35 of the 42 anomalies examined are illustrated in Figures 19 through 22. Figure 19 displays the long-term mean pressure pattern for the month of May. The weather chart for 1600 PST, 6 May, 1971 shown in Figure 20 illustrates the intensification of the low-pressure trough and its advance over Northern California. Figure 21 displays the long-term mean pressure pattern for the month of June; Figure 22 for 0400 PST, 1 June shows the intensification of the North Pacific high pressure cell and the displacement of the isobars toward the Pacific Coast. The synoptic weather situations shown in Figures 20 and 22 produced a

positive and a negative anomaly respectively, each of about two days duration.

The synoptic weather situations that were found to be related to the atmospheric pressure changes causing 41 of the 42 anomalies examined are as follows:

1. Intensification of the North Pacific high-pressure cell and displacement of the pressure gradient toward the Pacific Coast, producing above normal pressures at Monterey (12 cases).

2. Intensification of the predominant low-pressure trough over Mexico and the southwestern United States and its advance northward over Northern California, giving below normal pressures at Monterey (23 cases). Occasionally, low-pressure centers of small size formed within the enlarged low pressure trough.

3. Frontal passage with an associated decrease in pressure (5 cases).

4. Passage of a high-pressure center not related to the North Pacific high-pressure cell (1 case).

In examining the successive six-hourly weather charts, these synoptic weather situations were often closely associated with water-level anomalies of duration less than twelve hours, but these situations were not catalogued.

The close relationship found here between the occurrance of these synoptic weather situations and water-level anomalies suggests that the latter can be forecasted. By way of experiment, the National Weather Service six-hourly charts were re-examined without reference to any tabulation of water-level anomalies and it was possible to correctly forecast the occurrence of 41 of the 42 water-level anomalies of

duration greater than twelve hours. It was possible to forecast the amplitude of the water-level anomaly quantitatively. The abilty to forecast anomalies of less than twelve hours duration was only marginally demonstrated by this procedure.

In view of the fact that pressure variations causing water-level anomalies were due in most cases to either an eastward or westward migration of the isobaric gradient over Monterey due to either intensification or movement of the quasi-permanent high and low pressure systems in the region, it may be concluded that point measurement of the surface pressure at Monterey (values of which were used in this study) is probably more useful than pressure integrated over a large area of the sea surface around Monterey.

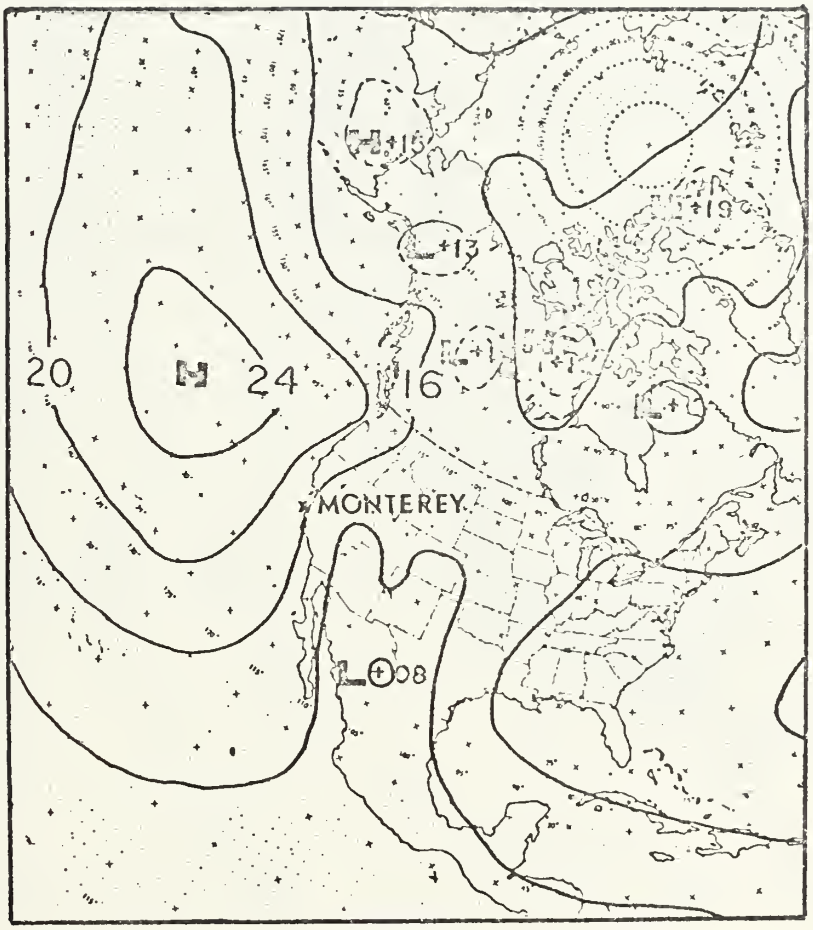


FIGURE 19: LONG-TERM MEAN PRESSURE PATTERN - MAY
(from Hesse and Stevenson, 1968)

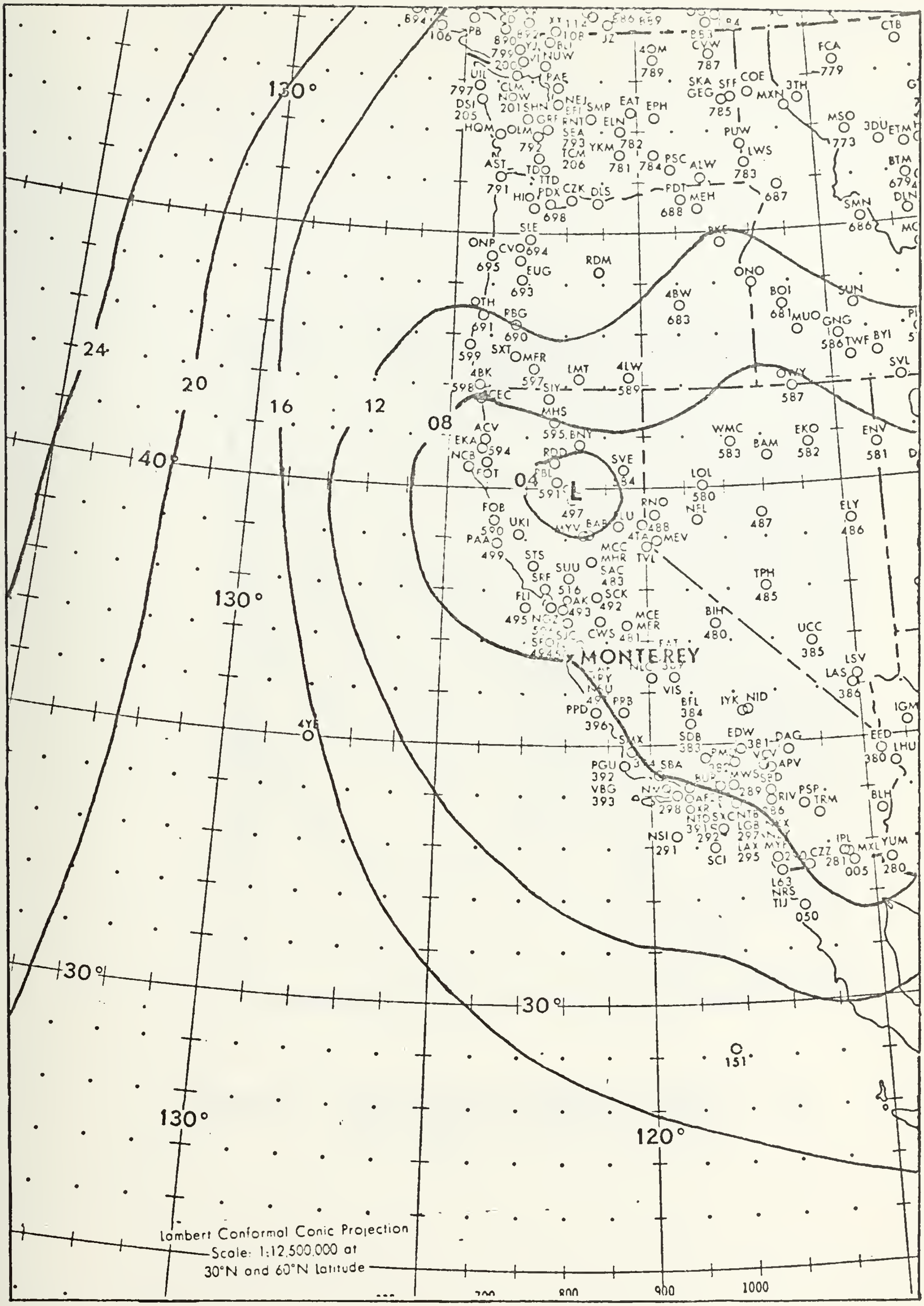


FIGURE 20: SEA LEVEL PRESSURE CHART - 1600, 6 MAY 1971

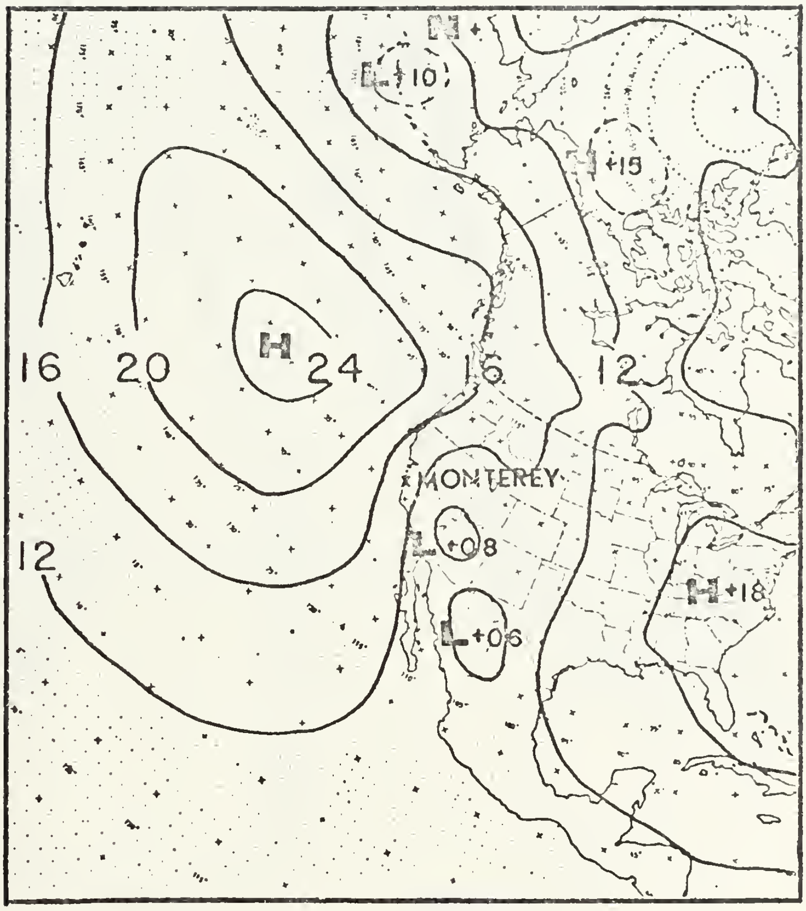


FIGURE 21: LONG-TERM MEAN PRESSURE PATTERN - JUNE
(from Hesse and Stevenson, 1968)

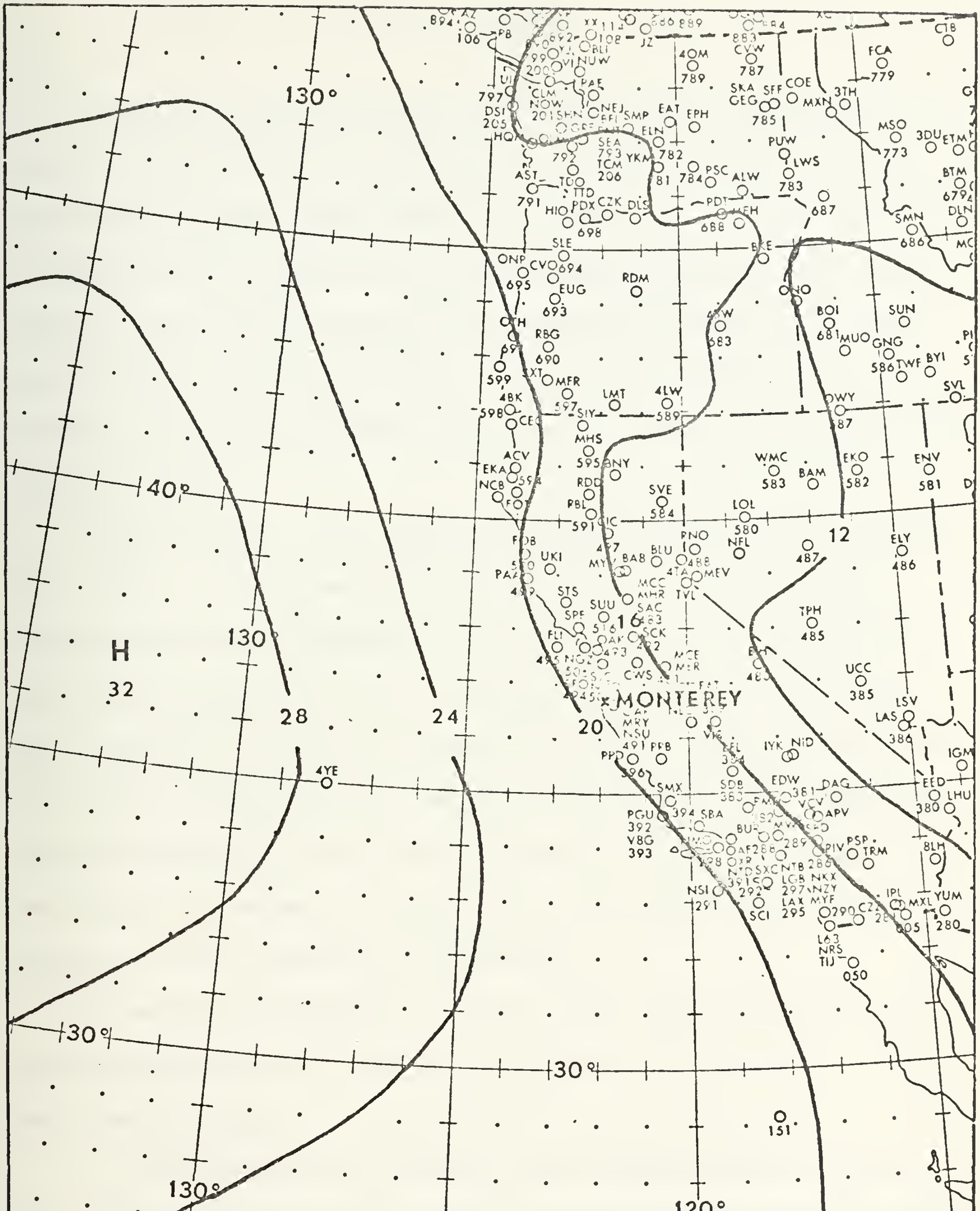


FIGURE 22: SEA LEVEL PRESSURE CHART - 0400, 1 JUNE 1971

## V. SUMMARY

A comparison of the predicted and observed tides at Monterey over the one-year period from 1 February 1971 through 31 January 1972 revealed that the hourly water-level differences did not exceed $\pm$ 0.9 feet in magnitude and that they were normally distributed about zero water level. A total of 263 water-level anomalies were identified, ranging from 2 to 362 hours in duration. 42 water-level anomalies were of a duration greater than 12 hours, and these were examined in detail with regard to cause.

It was determined that change in atmospheric pressure was the dominant cause. A regression analysis, by months, of the correlation between water-level difference and atmospheric pressure revealed that the water level responded in a near-hydrostatic manner. The response was a function of the rate of change of pressure. In those cases where the pressure changed rapidly, the water-level maxima lagged behind the pressure maxima up to three hours; however, the amplitude response of the water-level anomaly was approximately that expected from the pressure change assuming a hydrostatic relationship.

The changes in atmospheric pressure which caused the 42 water-level anomalies examined were found to be associated with four kinds of synoptic weather events:

1. Intensification of the North Pacific high-pressure cell and displacement of the pressure gradient toward the Pacific Coast, producing above normal pressures at Monterey (12 cases).

2. Intensification of the predominant low-pressure trough over Mexico and the southwestern United States and its advance northward

over Northern California, giving below normal pressures at Monterey (23 cases).

3. Frontal passage with an associated decrease in pressure (5 cases).

4. Passage of a high-pressure center not related to the North Pacific high-pressure cell (1 case).

Absence of wind stress as a factor in producing anomalies was attributed to the sheltered location of the tide gage from the prevailing onshore winds.

LIST OF REFERENCES


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2. Armstrong, J. B., "<u>The Effect of Meteorological Conditions on Sea Level</u>," Canada Department of Transport, Meteorological Branch, CIR-3747, TEC-429, 19 p., 1958.

3. Jacobs, W. C., "Sea Level Departures on the California Coast as Related to the Dynamics of the Atmosphere Over the North Pacific Ocean," <u>Journal of Marine Research</u>, v. 2, No. 3, p. 181-194, 19~~5~~8.
1939. PP

4. O'Connor, P., <u>Short-Term Sea Level Anomalies at Monterey, California</u>, Naval Postgraduate School, Monterey. M.S. thesis, 56 p., 1964.

5. Hesse, T. S., and N. M. Stevenson, <u>1962-1968 Monthly Hemispheric Means, Standard Deviations, and Diurnal Variations</u>, Fleet Numerical Weather Central, Technical Report 43, December 1968.

## APPENDIX A: TIDAL CONSTITUENTS FOR MONTEREY, CALIFORNIA

Monterey Municipal Wharf No. 2
1 February, 1971 - 31 January 1972
Prepared by:
Tides Branch
National Ocean Survey

| MSL(ft) | CONSTITUENT | H | KAPPA | KPR-K | KAPPA PRIME | SPEED |
|---|---|---|---|---|---|---|
| 5.945 | 1 $M_2$ | 1.605 | 297.05 | 11.91 | 309.0 | 28.9841 |
| | 2 $S_2$ | .416 | 296.13 | 3.78 | 300.0 | 30.0000 |
| | 3 $N_2$ | .371 | 270.56 | 16.26 | 286.8 | 28.4397 |
| | 4 $K_1$ | 1.191 | 97.88 | 1.56 | 99.4 | 15.0411 |
| | 5 $M_4$ | .002 | 175.68 | 23.81 | 199.5 | 57.9682 |
| | 6 $O_1$ | .742 | 81.82 | 10.35 | 92.2 | 13.9430 |
| | 7 $M_6$ | .002 | 123.40 | 35.72 | 159.1 | 86.9523 |
| | 8 $(MK)_3$ | .003 | 206.54 | 13.47 | 220.0 | 44.0252 |
| | 9 $S_4$ | .001 | 256.80 | 7.56 | 264.4 | 60.0000 |
| | 10 $(MN)_4$ | .002 | 72.72 | 28.17 | 100.9 | 57.4238 |
| | 11 $\lambda_2$ | .071 | 278.29 | 15.88 | 294.0 | 28.5126 |
| | 12 $S_6$ | .003 | 78.26 | 11.34 | 89.6 | 90.0000 |
| | 13 $\mu_2$ | .043 | 245.09 | 20.03 | 265.1 | 27.9682 |
| | 14 $(2N)_2$ | .042 | 248.06 | 20.62 | 268.7 | 27.8954 |
| | 15 $(OO)_1$ | .044 | 130.62 | -7.22 | 123.4 | 16.1391 |
| | 16 $\lambda_2$ | .010 | 312.95 | 8.13 | 321.1 | 29.4556 |
| | 17 $S_1$ | .037 | 209.04 | 1.89 | 210.9 | 15.0000 |
| | 18 $M_1$ | .040 | 105.73 | 5.92 | 111.6 | 14.4967 |
| | 19 $J_1$ | .071 | 106.91 | -2.79 | 104.1 | 15.5854 |
| | 20 Mm | .018 | 159.64 | -4.35 | 155.3 | .5444 |
| | 21 Ssa | .051 | 262.31 | -.66 | 261.7 | .0821 |
| | 22 Sa | .251 | 185.02 | -.33 | 184.7 | .0411 |
| | 23 Msf | .009 | 220.94 | -8.13 | 212.8 | 1.0159 |
| | 24 Mf | .019 | 135.54 | -8.78 | 126.8 | 1.0980 |
| | 25 $P_1$ | .023 | 69.82 | 14.12 | 83.9 | 13.4715 |
| | 26 $Q_1$ | .135 | 73.23 | 14.70 | 87.9 | 13.3987 |

APPENDIX A: TIDAL CONSTITUENTS FOR MONTEREY, CALIFORNIA (CONTINUED)

| MSL(ft) | CONSTITUENT | H | KAPPA | KPR-K | KAPPA PRIME | SPEED |
|---|---|---|---|---|---|---|
| | 27 $T_2$ | .018 | 265.48 | 4.11 | 269.6 | 29.9589 |
| | 28 $R_2$ | .003 | 238.35 | 3.45 | 241.8 | 30.0411 |
| | 29 $(ZQ)_1$ | .016 | 57.99 | 19.06 | 77.0 | 12.8543 |
| | 30 $P_1$ | .362 | 92.95 | 2.22 | 95.2 | 14.9589 |
| | 31 $(ZSM)_2$ | .004 | 127.09 | -4.35 | 122.7 | 31.0159 |
| | 32 $M_3$ | .006 | 5.31 | 17.86 | 23.2 | 43.4762 |
| | 33 $L_2$ | .047 | 317.40 | 7.55 | 325.0 | 29.5285 |
| | 34 $(ZMR)_3$ | .004 | 137.53 | 22.25 | 159.8 | 42.9271 |
| | 35 $K_2$ | .117 | 285.55 | 3.12 | 288.7 | 30.0821 |
| | 36 $M_8$ | .001 | 219.02 | 47.63 | 266.6 | 115.9364 |
| | 37 $(MS)_4$ | .001 | 326.23 | 15.69 | 341.9 | 58.9841 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES
of duration 24 hours or longer

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| FEB | 00/01 | 19/02 | 44 | Low Pressure Trough | 4 4 3 2 2 2 2 3 3 4 4 5 |
| 1971 | | | | | 4 3 4 3 3 3 3 2 1 3 4 3 |
| | | | | | 2 4 3 3 2 2 2 1 1 2 3 2 |
| | | | | | 2 2 2 3 2 2 2 2 |
| FEB | 08/11 | 18/17 | 155 | Weak Low Pressure Trough | 2 1 2 2 2 2 2 2 2 2 2 3 |
| | | | | | 2 4 1 2 1 1 2 2 2 2 2 2 |
| | | | | | 2 3 3 9 4 2 1 1 1 1 2 2 |
| | | | | | 2 1 0 0 2 1 0 2 2 2 2 2 |
| | | | | Intensification of Low Pressure Trough | 4 3 3 3 3 4 3 4 2 3 2 3 |
| | | | | | 2 2 2 1 1 3 3 2 3 1 4 3 |
| | | | | | 4 3 3 3 3 1 2 3 2 3 2 2 |
| | | | | | 3 1 2 1 1 2 1 1 4 2 2 1 |
| | | | | | 1 1 1 3 3 3 3 2 3 3 2 2 |
| | | | | | 2 0 1 1 1 1 3 4 3 4 3 4 |
| | | | | Frontal Passage with Associated Low Pressure | 4 4 5 4 6 4 5 6 7 7 7 7 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| FEB | | | | | 6 5 4 3 3 4 5 5 5 6 6 5<br>5 5 4 4 3 3 3 2 3 1 2 |
| MAR | 05/12 | 23/12 | 19 | Frontal Passage with Associated Low Pressure | 2 2 4 3 3 2 2 2 2 4 3 1<br>3 4 3 4 3 3 2 |
| MAR | 09/20 | 02/21 | 18 | Low Pressure Trough | 2 2 2 3 4 4 4 3 3 2 3 3<br>3 3 3 2 2 3 |
| MAR | 01/25 | 10/26 | 34 | Frontal Passage with Associated Low Pressure | 2 2 4 3 4 5 4 3 2 2 2 2<br>1 2 1 2 3 3 5 4 3 3 3 2<br>3 4 3 4 4 4 5 3 4 2 |
| MAR | 07/29 | 01/30 | 19 | Low Pressure Trough | 2 3 2 3 3 3 2 1 2 2 2 3<br>3 5 5 4 5 3 2 |
| APR | 14/13 | 03/15 | 38 | Frontal Passage with Associated Low Pressure | 4 3 2 3 3 3 4 4 3 4 4 5<br>3 4 4 3 3 3 3 2 3 2 3 3<br>4 4 3 3 4 3 3 3 3 3 3 2<br>2 2 |
| APR | 07/17 | 23/17 | 39 | Low Pressure Trough | 2 1 2 2 2 3 2 2 3 2 2 1<br>2 2 1 3 3 2 2 4 2 3 3 3<br>2 3 3 3 3 3 3 3 3 2 2 2<br>2 2 3 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| MAY | 12/05 | 07/07 | 44 | Formation of Low Pressure Center within Low Pressure Trough | 2 2 3 2 3 2 3 3 2 2 3 2<br>3 3 4 5 4 5 4 4 3 3 4 3<br>4 3 5 5 4-3 3 3 3 3 2 1<br>1 2 2 3 3 2 2 2 |
| MAY | 03/14 | 16/14 | 14 | Low Pressure Trough | 2 1 2 2 2 1 2 3 3 1 2 3<br>2 3 |
| MAY | 10/25 | 22/25 | 13 | Frontal Passage with Associated Low Pressure | 2 3 1 2 2 2 2 2 1 1 2 2<br>2 |
| JUN | 01/16 | 13/18 | 61 | Low Pressure Trough | 2 2 3 3 2 3 2 3 2 2 2 2<br>2 2 2 2 1 1 2 1 1 2 2 2<br>3 3 3 3 3 5 4 4 4 3 4 3<br>3 2 2 2 2 1 3 2 2 3 2 3<br>2 3 3 2 3 3 3 3 4 2 2 2<br>2 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| JUL | 00/18 | 11/18 | 12 | Slight Intensification of Low Pressure Trough | 2 1 2 1 2 2 1 2 2 2 2 2 |
| SEP | 15/13 | 03/19 | 133 | Intense Low Pressure Trough | 2 2 3 3 3 3 3 5 4 4 3 2 |
| | | | | | 2 3 2 3 4 3 3 3 2 3 3 2 |
| | | | | | 3 3 4 4 4 4 4 4 5 4 3 2 |
| | | | | | 3 3 2 3 3 4 3 3 3 4 2 2 |
| | | | | | 3 2 3 3 3 3 3 3 4 3 3 2 |
| | | | | Low Pressure Trough Weakening | 1 1 1 1 0 2 2 3 3 4 4 3 |
| | | | | | 2 1 1 1 2 3 3 4 5 4 4 2 |
| | | | | | 2 1 1 1 2 2 2 2 2 3 3 3 |
| | | | | | 2 2 2 1 2 2 2 2 3 3 4 3 |
| | | | | | 3 3 2 2 1 1 2 3 3 3 4 3 |
| | | | | | 3 2 1 1 2 2 2 1 1 2 3 3 |
| | | | | | 2 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| OCT | 06/07 | 19/07 | 14 | Formation of Low Pressure Cell of | 3 2 2 2 2 3 1 3 3 4 3 3 |
| | | | | Short Duration | 2 2 |
| OCT | 18/12 | 14/17 | 117 | Intensification of Prevailing Low | 2 2 3 3 3 2 3 3 2 1 1 1 |
| | | | | Pressure Trough | 1 2 2 3 2 3 2 2 2 2 1 1 |
| | | | | | 1 1 2 1 2 3 2 2 2 3 2 2 |
| | | | | | 1 2 1 2 3 3 2 4 3 1 1 3 |
| | | | | | 2 2 3 3 2 1 1 3 2 2 2 3 |
| | | | | | 2 2 1 2 2 3 3 2 2 2 3 3 |
| | | | | | 2 1 3 3 4 3 4 2 4 2 3 3 |
| | | | | Formation of Low Pressure Cell | 3 3 3 3 3 4 5 4 4 1 3 4 |
| | | | | | 2 2 3 3 3 4 4 4 2 2 1 2 |
| | | | | | 2 2 1 2 3 4 3 3 2 |
| NOV | 02/15 | 15/16 | 38 | Low Pressure Trough | 3 2 2 3 1 4 5 3 4 4 3 4 |
| | | | | | 4 4 2 1 2 3 1 2 3 4 3 3 |
| | | | | | 3 4 4 4 4 3 3 2 3 4 3 3 |
| | | | | | 3 3 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| NOV | 07/22 | 21/22 | 15 | Weak Low Pressure Trough | 2 1 2 2 2 1 2 2 1 2 2 3 |
| | | | | | 2 1 2 |
| DEC | 10/21 | 22/28 | 157 | Intense Low Pressure Cell Forms | 2 2 3 3 4 4 5 4 6 4 6 7 |
| | | | | | 7 7 7 7 7 7 7 7 6 5 5 5 |
| | | | | | 5 5 4 4 4 4 2 3 2 1 2 3 |
| | | | | | 3 4 4 4 6 5 5 4 5 4 4 5 |
| | | | | | 5 5 6 4 5 5 5 5 4 5 4 5 |
| | | | | | 5 5 6 6 6 7 6 5 4 5 6 7 |
| | | | | | 5 4 7 7 6 6 6 6 5 4 5 4 |
| | | | | | 4 5 4 4 4 5 5 5 3 3 4 5 |
| | | | | | 5 6 5 6 7 7 7 7 7 7 7 8 |
| | | | | | 7 8 7 8 9 7 9 8 6 5 6 5 |
| | | | | | 7 6 6 6 6 6 6 7 6 6 6 5 |
| | | | | | 5 4 4 4 3 3 4 3 2 2 2 3 |
| | | | | | 2 2 3 1 2 2 3 3 3 4 4 2 |
| | | | | | 2 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| DEC | 17/31 | 13/01 | 21 | Weak Low Pressure Trough | 2 2 1 2 3 3 3 1 1 2 1 1<br>2 2 3 4 3 3 1 2 3 |
| JAN<br>1972 | 23/01 | 12/04 | 62 | Marked Intensification of Previous Low Pressure Trough | 2 2 2 3 3 3 3 4 4 5 4 4<br>4 4 4 3 2 4 3 2 3 2 2 6<br>4 5 6 4 6 5 5 5 5 4 7 7<br>5 5 4 5 2 3 2 1 2 1 2 1<br>2 2 3 2 2 3 2 2 2 3 3 1<br>2 2 |
| JAN | 20/06 | 16/07 | 21 | Low Pressure Trough | 2 2 2 2 1 3 3 3 3 3 4 3<br>4 3 5 4 3 3 3 3 3 |
| JAN | 22/07 | 12/08 | 15 | Formation of Weak Low Pressure Cell - Result of Previous Trough | 2 2 2 2 2 2 32 1 1 2 2<br>2 2 2 |

APPENDIX B: POSITIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| JAN | 01/16 | 16/17 | 40 | Low Pressure Trough | 2 2 3 3 4 3 3 3 3 2 2 2<br>3 2 1 2 2 1 1 1 2 2 2 2<br>1 2 2 2 3 2 2 3 3 3 2 3<br>3 2 1 2 |
| JAN | 00/18 | 14/18 | 15 | Weak Low Pressure Trough | 2 1 3 1 1 3 2 1 2 2 3 3<br>4 2 3 |
| JAN | 04/25 | 22/25 | 19 | Frontal Passage with Associated Low Pressure | 3 1 1 2 2 2 4 3 3 2 3 2<br>2 2 1 1 2 2 2 |
| JAN | 00/27 | 12/27 | 13 | Low Pressure Trough | 2 2 2 3 2 3 3 4 3 2 2 2<br>2 |
| JAN | 03/31 | 23/31 | 21 | Low Pressure Trough | 2 1 3 3 3 4 4 4 4 2 3 3<br>4 2 2 3 2 2 2 3 3 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| FEB | 13/24 | 15/11 | 362 | Intensification of Prevalent Pacific | 2 2 2 2 2 1 1 2 2 2 2 2 |
| 1971 | | | | High Pressure Cell and Displacement | 3 3 3 3 4 2 2 4 2 2 4 5 |
| | | | | Toward Pacific Coast | 6 5 6 6 5 7 5 5 6 5 5 6 |
| | | | | | 6 5 6 7 6 6 6 5 6 5 6 4 |
| | | | | | 5 5 5 5 6 6 5 5 4 4 3 4 |
| | | | | | 4 5 5 5 5 5 3 3 4 3 4 3 |
| | | | | | 4 5 4 4 4 3 2 2 2 2 3 3 |
| | | | | | 3 3 3 2 3 2 3 2 1 3 2 3 |
| | | | | | 4 3 3 3 2 2 1 1 1 1 2 2 |
| | | | | | 2 3 4 3 3 3 3 2 3 4 4 5 |
| | | | | | 5 6 4 5 4 5 5 4 4 5 5 6 |
| | | | | Intense High Pressure Cell Extending | 6 7 7 6 7 7 7 6 6 6 6 6 |
| | | | | Inland | 6 6 6 7 6 6 6 6 5 6 5 7 |
| | | | | | 6 7 7 6 6 7 6 5 5 4 3 5 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| | | | | | 4 3 4 4 3 5 4 2 2 3 3 3 |
| | | | | | 3 3 4 4 4 3 0 3 3 2 1 1 |
| | | | | | 1 0 1 1 2 2 3 4 3 2 3 3 |
| | | | | | 4 4 3 3 5 5 5 5 5 5 4 3 |
| | | | | | 3 3 3 3 5 4 4 4 5 5 4 4 |
| | | | | | 3 3 3 4 4 4 5 5 4 4 4 4 |
| | | | | | 3 3 2 2 3 4 3 5 4 3 4 4 |
| | | | | | 3 2 1 2 2 2 3 4 4 3 3 3 |
| | | | | Formation of Low Pressure Trough | 2 2 0 0 0 1 1 1 2 3 3 2 |
| | | | | | 2 1 0 1 0 0 1 2 3 4 2 2 |
| | | | | | 2 2 0 1 1 2 2 2 3 2 1 2 |
| | | | | | 1 1 1 1 0 1 1 2 3 3 2 3 |
| | | | | | 3 2 2 1 1 2 2 2 3 2 4 2 |
| | | | | | 2 3 2 2 1 1 2 2 3 2 2 1 |
| | | | | | 2 3 3 3 1 2 1 2 2 2 4 2 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| | | | | | 3 1 2 1 1 0 0 1 2 1 2 1 |
| | | | | | 2 2 |
| MAR | 23/13 | 08/16 | 58 | Intensification of Prevalent Pacific | 2 3 3 4 3 4 4 3 2 2 2 2 |
| | | | | High Pressure Cell and Displacement | 2 2 3 6 3 4 3 2 1 0 2 1 |
| | | | | Toward Pacific Coast | 2 4 4 5 3 5 5 3 3 2 2 2 |
| | | | | | 3 2 3 6 3 2 3 2 2 2 1 0 |
| | | | | | 2 2 3 3 2 2 3 2 2 2 |
| APR | 03/02 | 15/02 | 13 | High Pressure Intrusion Eminating from | 2 2 3 3 3 4 2 2 2 1 1 2 |
| | | | | Pacific High Pressure Cell | 2 |
| MAY | 22/15 | 13/17 | 40 | Intensification of Prevalent Pacific | 2 3 2 2 3 1 2 2 1 3 3 3 |
| | | | | High Pressure Cell and Displacement | 2 1 3 2 2 2 2 3 3 3 3 4 |
| | | | | Toward Pacific Coast | 4 5 4 2 2 2 3 2 1 1 2 3 |
| | | | | | 2 2 2 2 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| MAY | 09/31 | 04/02 | 44 | Displacement of Pacific High Pressure Cell Toward Pacific Coast | 2 2 2 1 2 2 2 2 2 2 2 2<br>3 3 3 3 3 3 2 2 3 2 2 2<br>2 2 2 2 2 2 2 2 2 2 2 2<br>3 2 3 2 2 2 1 2 |
| JUN | 09/03 | 23/03 | 15 | Displacement of Pacific High Pressure Cell Toward Pacific Coast | 2 2 1 2 1 2 2 2 2 3 2 2<br>2 1 2 |
| JUN | 10/04 | 22/04 | 13 | Displacement of Pacific High Pressure Cell Toward Pacific Coast | 2 1 2 2 2 2 2 2 2 2 2 2<br>2 |
| AUG | 04/18 | 15/18 | 12 | Slight Displacement of Pacific High Pressure Cell Toward Pacific Coast | 2 2 3 1 2 2 2 2 1 2 2 2 |
| AUG | 22/19 | 17/20 | 21 | Slight Displacement of Pacific High Pressure Cell Toward Pacific Coast | 2 2 1 2 1 2 2 2 2 2 3 3<br>3 1 2 3 2 1 1 2 2 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| OCT | 08/28 | 23/31 | 88 | Passage of Intense High Pressure Cell | 2 2 2 4 2 2 4 3 3 3 2 2 |
| | | | | | 2 3 4 3 3 3 4 3 2 4 4 4 |
| | | | | | 3 3 4 3 4-5 4 3 3 3 4 4 |
| | | | | | 4 3 2 4 4 5 5 4 4 4 4 4 |
| | | | | | 2 2 2 1 4 3 3 3 3 3 3 2 |
| | | | | | 3 2 1 2 2 2 3 3 1 3 2 1 |
| | | | | | 2 2 1 0 1 2 2 2 2 2 1 2 |
| | | | | | 2 3 3 2 |
| NOV | 12/01 | 04/06 | 113 | Intensification of Pacific High Pressure | 2 2 2 4 2 2 4 3 3 3 2 2 |
| | | | | Cell and Displacement Towards Pacific | 2 3 2 3 4 3 4 3 2 4 4 4 |
| | | | | Coast | 3 3 4 3 4 5 4 3 3 3 4 4 |
| | | | | | 4 3 2 4 4 5 5 4 4 4 4 4 |
| | | | | | 2 2 2 1 4 3 3 3 3 3 3 6 |
| | | | | | 3 2 1 2 2 2 3 3 1 3 2 1 |
| | | | | | 2 2 1 0 1 2 2 2 2 2 1 2 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| | | | | | 2 3 3 2 2 1 2 3 3 3 2 2 |
| | | | | | 2 2 2 2 2 2 3 3 3 3 3 2 |
| | | | | | 3 3 3 2 2 |
| NOV | 04/29 | 23/30 | 44 | Unexplained: Area under influence of | 2 2 2 2 2 1 3 3 2 3 3 4 |
| | | | | low pressure cell of broad geographic | 4 4 5 4 3 3 3 2 2 3 3 3 |
| | | | | extent but all hourly water level | 3 4 3 3 3 3 2 3 3 3 4 3 |
| | | | | differences are negative | 4 3 3 3 3 3 2 2 |
| DEC | 05/04 | 05/17 | 313 | Intensification of Pacific High Pressure | 2 2 2 1 2 2 2 2 2 4 3 3 |
| | | | | Cell and Displacement Toward Pacific | 3 4 5 5 4 5 5 3 4 4 4 4 |
| | | | | Coast | 4 4 4 5 4 4 5 4 4 4 3 3 |
| | | | | | 4 3 4 4 3 3 2 3 3 2 2 2 |
| | | | | | 2 2 3 3 2 3 2 3 2 3 1 1 |
| | | | | | 1 2 2 2 2 1 2 2 2 2 2 2 |
| | | | | | 3 2 2 3 3 4 5 4 4 4 3 3 |
| | | | | | 3 3 3 3 3 4 3 4 4 2 2 3 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| | | | | | 3 3 4 4 6 6 6 7 6 6 6 6 |
| | | | | | 5 4 5 4 4 5 3 4 4 3 4 3 |
| | | | | | 3 3 4 3 4 4 5 4 5 5 4 4 |
| | | | | | 3 3 2 2 2 2 1 3 0 2 1 2 |
| | | | | | 2 2 2 3 2 1 2 2 5 4 4 3 |
| | | | | | 3 3 2 3 2 2 3 3 4 3 3 3 |
| | | | | | 3 2 3 2 4 5 4 4 5 4 5 4 |
| | | | | | 3 4 5 4 3 4 4 4 4 4 3 3 |
| | | | | Frontal Passage with Associated Decrease | 1 2 1 1 0 0 0 1 1 2 2 2 |
| | | | | of Pressure | 1 3 2 1 1 2 2 2 2 4 1 1 |
| | | | | | 2 2 1 1 2 3 1 2 3 3 3 4 |
| | | | | | 3 3 3 2 3 3 3 3 3 3 3 1 |
| | | | | | 1 2 2 2 2 1 1 2 2 2 1 2 |
| | | | | | 1 1 2 1 2 2 1 2 1 2 1 1 |
| | | | | | 1 2 2 1 2 2 2 1 2 3 4 4 |

APPENDIX B: NEGATIVE WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | ASSOCIATED WEATHER EVENTS | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|---|
| | | | | | 3 3 3 5 4 4 5 5 5 5 5 4<br>4 4 4 3 3 4 3 3 8 5 5 5<br>6 2 4 4 5-4 4 4 3 3 3 3<br>3 |
| JAN 1972 | 06/11 | 02/12 | 20 | Intensification of Pacific High Pressure Cell and Displacement Toward Pacific Coast | 2 2 2 2 3 2 2 2 2 2 1 2<br>1 2 3 2 2 2 2 2 |

APPENDIX C: POSITIVE EXTREME WATER LEVEL ANOMALIES

| MONTH | BEGIN | END | DUR | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|
| FEB 1971 | 00/01 | 01/01 | 2 | 4 4 |
| | 09/01 | 14/01 | 6 | 4 4 5 4 3 4 |
| | 11/12 | 12/12 | 2 | 4 4 |
| | 13/13 | 15/13 | 3 | 4 3 4 |
| | 06/14 | 08/14 | 3 | 4 3 4 |
| | 03/16 | 11/17 | 33 | 4 3 4 3 4 4 4 5 4 6 4 5 |
| | | | | 6 7 7 7 7 6 5 4 3 3 4 5 |
| | | | | 5 5 6 6 5 5 5 4 4 |
| MAR | 18/12 | 20/12 | 3 | 4 3 4 |
| | 13/20 | 15/20 | 3 | 4 4 4 |
| | 03/25 | 07/25 | 5 | 4 3 4 5 4 |
| | 19/25 | 20/25 | 2 | 5 4 |
| | 02/26 | 09/26 | 8 | 4 3 4 4 4 5 3 4 |
| | 20/29 | 23/29 | 4 | 5 5 4 5 |
| APR | 00/12 | 04/12 | 4 | 4 3 4 4 |
| | 20/13 | 04/14 | 9 | 4 4 3 4 4 5 3 4 4 |
| | 14/14 | 15/14 | 2 | 4 4 |
| MAY | 02/06 | 16/06 | 15 | 4 5 4 5 4 4 3 3 4 3 4 3 |
| | | | | 5 5 4 |
| JUN | 06/17 | 11/17 | 6 | 5 4 4 4 3 4 |

APPENDIX C: POSITIVE EXTREME WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|
| SEP | 16/09 | 07/09 | 2 | 5 6 |
| | 23/11 | 01/12 | 3 | 4 5 4 |
| | 22/12 | 01/13 | 3 | 5 7 7 |
| | 22/13 | 01/14 | 3 | 5 4 4 |
| | 17/14 | 00/15 | 8 | 4 4 4 4 4 4 5 4 |
| | 12/16 | 13/16 | 2 | 4 4 |
| | 22/16 | 01/17 | 4 | 4 5 2 2 |
| OCT | 11/16 | 13/16 | 3 | 4 5 4 |
| NOV | 07/15 | 15/15 | 9 | 4 5 3 4 4 3 4 4 4 |
| | 03/16 | 06/16 | 4 | 4 4 4 4 |
| DEC | 14/21 | 15/22 | 26 | 4 4 5 4 6 5 6 7 7 7 7 7 |
| | | | | 7 7 7 7 6 5 5 5 5 5 4 4 |
| | | | | 4 4 |
| | 23/23 | 04/28 | 103 | 4 4 4 6 5 5 4 5 4 4 5 5 |
| | | | | 5 6 4 5 5 5 5 4 5 4 5 5 |
| | | | | 5 6 6 6 7 6 5 4 5 6 7 5 |
| | | | | 4 7 7 6 6 6 6 5 4 5 4 4 |
| | | | | 5 4 4 4 5 5 5 3 3 4 5 5 |
| | | | | 6 5 6 7 7 7 7 7 7 7 8 7 |
| | | | | 8 7 8 9 7 9 8 6 5 6 5 7 |
| | | | | 6 6 6 6 6 6 6 7 6 6 6 5 |

APPENDIX C: POSITIVE EXTREME WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|
| DEC | | | | 5 4 4 4 3 3 4 |
| | 19/28 | 20/28 | 2 | 4 4 |
| JAN 1972 | 06/02 | 13/02 | 8 | 4 4 5 4 4 4 4 4 |
| | 22/02 | 14/03 | 17 | 6 4 5 6 4 6 5 5 5 5 4 7 |
| | | | | 7 5 5 4 5 |
| | 06/07 | 11/07 | 6 | 4 3 4 3 5 4 |
| | 08/31 | 11/31 | 4 | 4 4 4 4 |

APPENDIX C: NEGATIVE EXTREME WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|
| FEB 1971 | 05/09 | 07/09 | 3 | 4 6 7 |
| | 05 25 | 18/27 | 62 | 4 2 2 4 2 2 4 5 6 5 6 6<br>5 7 5 5 6 5 5 6 6 5 6 7<br>6 6 6 5 6 5 6 4 5 5 5 5<br>6 6 5 5 4 4 3 4 4 5 5 5<br>5 5 5 3 3 4 3 4 3 4 5 4<br>4 4 |
| MAR | 11/01 | 20/03 | 58 | 4 4 5 5 6 4 5 4 5 5 4 4<br>5 5 6 6 7 7 6 7 7 7 6 6<br>6 6 6 6 6 6 7 6 6 6 6 5<br>6 5 7 6 7 7 6 6 7 6 5 5<br>4 3 5 4 3 4 4 3 5 4 |
| | 04/04 | 06/04 | 3 | 4 4 4 |
| | 02/05 | 12/05 | 11 | 4 4 3 3 5 5 5 5 5 5 4 |
| | 18/05 | 13/06 | 20 | 5 4 4 4 5 5 4 4 3 3 3 4<br>4 4 5 5 4 4 4 4 |
| | 19/06 | 01/07 | 7 | 4 3 5 4 3 4 4 |
| | 09/07 | 10/07 | 2 | 4 4 |
| | 02/14 | 05/14 | 4 | 4 3 4 4 |
| | 14/14 | 16/14 | 3 | 6 3 4 |
| | 00/15 | 05/15 | 6 | 4 4 5 3 5 5 |
| MAY | 21/16 | 00/17 | 4 | 4 4 5 4 |

APPENDIX C: NEGATIVE EXTREME WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|
| JUL | 15/10 | 16/10 | 2 | 4 4 |
| OCT | 05/29 | 07/30 | 27 | 4 4 4 3 3 4 3 4 5 4 3 3 |
| | | | | 3 4 4 4 3 2 4 4 5 5 4 4 |
| | | | | 4 4 4 |
| NOV | 09/02 | 11/03 | 27 | 4 4 4 3 3 4 3 4 5 4 3 3 |
| | | | | 3 4 4 4 3 2 4 4 5 5 4 4 |
| | | | | 4 4 4 |
| | 15/29 | 19/29 | 5 | 4 4 4 5 4 |
| | 14/30 | 16/30 | 3 | 4 3 4 |
| DEC | 18/04 | 20/05 | 27 | 4 5 5 4 5 5 3 4 4 4 4 4 |
| | | | | 4 4 5 4 4 5 4 4 4 3 3 4 |
| | | | | 3 4 4 |
| | 10/07 | 14/07 | 5 | 4 5 4 4 4 |
| | 22/07 | 01/08 | 4 | 4 3 4 4 |
| | 07/08 | 03/09 | 21 | 4 4 6 6 6 7 6 6 6 6 5 4 |
| | | | | 5 4 4 5 3 4 4 3 4 |
| | 07/09 | 17/09 | 10 | 4 3 4 4 5 4 5 5 4 4 |
| | 13/10 | 15/10 | 3 | 5 4 4 |
| | 09/11 | 02/12 | 18 | 4 5 4 4 5 4 5 4 3 4 5 4 |
| | | | | 3 4 4 4 4 4 |
| | 15/15 | 16/15 | 2 | 4 4 |

APPENDIX C: NEGATIVE EXTREME WATER LEVEL ANOMALIES (Cont)

| MONTH | BEGIN | END | DUR | HOURLY WATER LEVEL DIFFERENCES |
|---|---|---|---|---|
| DEC | 20/15 | 07/16 | 12 | 5 4 4 5 5 5 5 5 4 4 4 4 |
| | 13/16 | 00/17 | 12 | 8 5 5 5 6 3 4 4 5 4 4 4 |
| JAN 1972 | 07/24 | 09/24 | 3 | 5 3 5 |

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Harold V. Maixner, Jr.

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ABSTRACT

A comparison of the predicted and observed tides at Monterey, California conducted over the period of a year revealed that the hourly water-level differences did not exceed $\pm$ 0.9 feet in magnitude. 263 water-level anomalies of duration up to 362 hours were identified, of which 42 were of duration greater than twelve hours. It was determined that change in atmospheric pressure is the dominant causitive factor of hourly water-level differences and that the water-level response is approximately hydrostatic. The changes in atmospheric pressure associated with the 42 water-level anomalies examined were found to be manifestations of the eastward or westward migration of the isobaric gradient due to either intensification or movement of the quasi-permanent high and low pressure systems in the region.

| KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Tides | | | | | | |
| Tidal constituents for Monterey, California | | | | | | |
| Tide predictions versus observations | | | | | | |
| Water-level anomalies | | | | | | |
| Water-level anomalies related to atmospheric pressure changes | | | | | | |
| Water-level anomalies related to synoptic weather situations | | | | | | |
| Hydrostatic response of ocean level | | | | | | |
| Synoptic weather situations causing water-level anomalies | | | | | | |

Thesis
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